US Bureau of Naval personnel

DRAFTSMAN 1 & C

NAVY TRAINING COURSES

NAVPERS 10475

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Prepared by

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSES

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ACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
SERVICE	4 mos. service—or completion of recruit training.	6 mos. as E–2 or 8 mos. total service.	6 mos. as E–3 or 14 mos. total service.	12 mos. as E–4.	12 mos. as E–5; total service at least 36 mos.	36 mos as E–6
SCHOOL	Recruit Training.		Class A for PR3, PRS3.		Class B for MN1	Class B for AGCA, MNCA, MUCA.
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.			
PRACTICAL FACTORS	Locally prepared check-offs.	Records of Practical Factors, NavPers 760, must be completed for E–3 and all PO advancements.				
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.			
EXAMINATIONS	Locally prepared tests.		Service-wide examinations required for all PO advancements.			
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Required for E–3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed.				
AUTHORIZATION	Commanding Officer		U. S. Naval Examining Center			BuPers
	TARS are advanced to fill vacancies and must be approved by district commandants or CNARESTRA.					

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
	FOR THESE DRILLS PER YEAR						
TOTAL TIME IN GRADE	24 OR 48 12 NON-DRILLING	9 mos. 9 mos. 12 mos.	9 mos. 15 mos. 24 mos.	15 mos. 21 mos. 24 mos.	18 mos. 24 mos. 36 mos.	24 mos. 36 mos. 48 mos.	36 mos. 42 mos. 48 mos.
DRILLS ATTENDED IN GRADE#	48 24 12	27 16 8	27 16 13	45 27 18	54 32 20	72 42 32	108 64 38
TOTAL TRAINING DUTY IN GRADE#	24 OR 48 12 NON-DRILLING	14 days 14 days None	14 days 14 days None	14 days 14 days 14 days	14 days 28 days 14 days	28 days 42 days 28 days	42 days 42 days 28 days
PERFORMANCE TESTS				Specific ratings must complete applicable performance tests before taking examination.			
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 1316, must be completed for all advancements.					
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.					
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.					
AUTHORIZATION		District commandant or CNARESTRA					BuPers

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

#Active duty periods may be substituted for drills and training duty.

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

PREFACE

This book was written for men in the Navy and Naval Reserve who are studying for advancement to Draftsman 1 or Draftsman Chief. The qualifications for advancement are listed in appendix II. Because examinations for promotion are based on these qualifications, it is suggested that you refer to them as you read the text.

See the Reading List on page viii for the basic books which you should read before taking the Navy-wide examination for advancement in rating. This list is taken from *Training Publications for Advancement in Rating*, NavPers 10052, which is revised about once a year.

As one of the NAVY TRAINING COURSES, this book was prepared by the U. S. Navy Training Publications Center, with the assistance of the Draftsman School, NAVSCON, Port Hueneme, California, for the Bureau of Naval Personnel.

STUDY GUIDE

The tables which follow indicate the chapters of this book you should study. Use Table 1 if you are a Draftsman 2 studying for advancement to Draftsman 1. Use Table 2 if you are a Draftsman 1 studying for advancement to Chief Draftsman. If you are in the regular Navy, use the column headed DM in each case. This column designates the general service rating to which every chapter of this book applies. If you belong to the Reserve, use the column headed by your particular emergency service rating, either DMM (Mechanical Draftsman), DMS (Structural Draftsman), DME (Electrical Draftsman), DMT (Topographic Draftsman), or DMI (Illustrative Draftsman).

TABLE 1

Chapter	DM1	DMM1	DMS1	DME1	DMT1	DMI1
1	X	X	X	X	X	X
2	X	X	X	X	X	X
3	X	X	X	X	X	X
4	X	X	X	X	X	-----------
5	X	X	--------	--------	--------	-----------
6	X	X	--------	--------	--------	-----------
7	X	--------	X	--------	X	-----------
8	X	--------	--------	X	--------	-----------
9	X	--------	--------	--------	X	-----------
10	X	--------	--------	--------	X	-----------
11	X	--------	--------	--------	--------	X

TABLE 2

Chapter	DMC	DMMC	DMSC	DMEC	DMTC	DMIC
1	X	X	X	X	X	X
2	X	X	X	X	X	X
3						
4						
5	X	X				
6	X	X				
7	X		X			
8	X			X		
9	X				X	
10	X				X	
11	X					X

READING LIST

NAVY TRAINING COURSES

Draftsman 3, NavPers 10471
Draftsman 2, NavPers 10473
Basic Machines, NavPers 10624 (Chapters 1–9)
Mathematics, Vol. I, NavPers 10069–B
Mathematics, Vol. II, NavPers 10070–A
Advanced Mathematics, NavPers 10071

OTHER PUBLICATIONS

Engineering Drawing. French, Thomas E. New York: McGraw-Hill Book Company, Inc. 7th Ed.

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Educational Services Officer.* A partial list of those courses applicable to your rating follows:

Number	*Title*
MC 166 or CC 166	*Advanced Algebra*
MC 176 or CC 176	*Plane Geometry I*
MC 177 or C 177	*Plane Geometry II*
MB 188 or B 188	*Trigonometry*
MC 290 or CC 290	*Physics I*
MA 517	*College Physics*
MB 772 or CB 772	*Elementary Architectural Drawing*

* Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified in the active duty orders.

CONTENTS

DRAFTSMAN 1 & C

CHAPTER 1

THE NAVY DRAFTSMAN

YOUR PLACE IN THE NEW NAVY

Gone are the days when the Navy could be considered as primarily an offensive force. It must keep us linked with our allies across the oceans of the world. It must support our policies, or those policies must fail. Yet, this new Navy, with its enormously complex role in world affairs, is, like all navies of the past, only as good as the individuals who man its ships.

Admiral Arleigh A. Burke, Chief of Naval Operations, has said, "Never in the Navy's history have its petty officers, as a group, been more important or more impressive. The Navy is only as good as its petty officers and it is significant that the U. S. Navy is the world's best."

As a petty officer in the Navy, you are first of all a military man. You are a fighting man in an organization where heroics are less important than teamwork, but where you may be called upon to be a hero any day. It is your business to know your military duties, and to lead the men under you well and wisely.

But you are also a technician. Today's Navy could not exist were it not for the great technological advances which have taken place in the last two decades and which will continue. And because the language of technology is drafting, your specialty is indispensable to the modern Navy.

As a Draftsman 1 or C, you have a key job. Each drawing that you make, check, or initial must be as correct as you can make it. If a drawing is wrong, it may cost the Navy thousands of dollars, but it may cost even more; it can cost the lives of shipmates. In peace and war, you must be a perfectionist; workmanship is your watchword.

YOUR RATING

Since the number of men in the Navy is limited in peacetime, the specialization of duties within a rating must be limited. Each job assignment requires the performance of many different duties. For this reason, the ratings of petty officers in the peacetime regular Navy are termed general service ratings.

A general service Draftsman must be qualified in all the techniques and skills of the rating. He must understand the practice and conventions relating to many different types of drawings. Furthermore, he must know how his drawing is to be used in order to present clearly the information that must be shown. This means that he must know something concerning the nomenclature, materials, equipment, operations, and methods of many allied trades.

In peacetime, a Draftsman may be assigned to a billet aboard a repair ship, a survey ship, or an aircraft carrier, or at an advanced base, a shore station, or an airfield. He may be required to prepare engineering drawings, maps or charts, or illustrations, posters, and training aids.

Under mobilization conditions, when the number of men in the Navy is greatly increased, Draftsmen, both regular Navy and Naval Reserve, are divided into five specialized groups called emergency service ratings.

Mechanical Draftsmen (DMM) work on drawings of machines, mechanisms, and plumbing or heating and ventilating systems.

Structural Draftsmen (DMS) work on architectural and structural drawings of all buildings and structures

typical of airfields, advanced bases, and shore stations, and drawings of ship and aeronautical structures.

Electrical Draftsmen (DME) work on drawings of electrical circuits and power transmission and distribution systems.

Topographical Draftsmen (DMT) work on topographic drawings, maps, and hydrographic charts.

Illustrators (DMI) work on drawings, posters, and illustrations for publication, and on training aids for use in Navy training programs.

As you can see, the DMS rating includes architectural drafting, the DMT includes hydrographic, and the DMM includes machine drafting. Therefore, the peacetime general service rating must include all of these fields.

In civilian industry, draftsmen are specialists, working in one field, such as architectural drafting or tool design, with the various work levels extending into design work. In view of the broad scope of the Navy rating, design qualifications are not included and Navy design work is usually performed by naval officers, civil service engineers, or civilian contract engineers. The rates of DM3, DM2, DM1, and DMC correspond in general to the following work levels common to civilian drafting; tracer (DM3), detail man (DM2), layout man (DM1), and chief draftsman (DMC).

To qualify as a tracer, the DM3 should be able to trace, copy, and revise existing drawings, such as originals, prints, sketches, illustrations, maps and charts, using both ink and pencil instruments and equipment, and adding freehand and mechanical lettering as required; to operate reproduction machines; to do filing; and to perform routine maintenance of instruments and equipment.

The DM2, as a detail man, should be able to make original drawings of all kinds for reproduction, on the basis of information and directions supplied by the supervisor in charge of the drafting room, and to perform computations required for dimensions pertaining to detail drafting.

The layout man, DM1, should be able to make original engineering and illustration layouts, not for reproduction, but for approval and information purposes only, to check all drawings, and to keep drafting room records.

The DMC, chief draftsman, should be able to administer a drafting room, to initiate filing and record systems, to determine the drawings required for a job, and to assign work, instructing the draftsmen as required.

In actual practice, Draftsmen must often of necessity perform duties over and above their pay grades. Opportunities abound for valuable experience in advanced work.

REQUIREMENTS FOR ADVANCEMENT

The specific military and professional requirements for advancement in rating are published in the *Manual of Qualifications for Advancement in Rating*, NavPers 18068 (Revised). This publication is known throughout the Navy as the *Quals Manual*. It is an important source of information for any enlisted man who is preparing for advancement, since it lists what he must know and what he must be able to do in order to advance in his rating. Every ship and every station should have copies of the *Quals Manual*.

Note that periodic changes to the *Quals Manual* are issued by the Bureau of Naval Personnel. Be sure you obtain the latest change pertaining to your rating. For example, the Draftsman rating was altered significantly in Change 8 to the *Quals Manual*, and the professional factors from this change are included in appendix II of this training course.

The military requirements for advancement are also published and discussed in the Navy training courses on the military requirements. The basic reference text is *Military Requirements for Petty Officer 1/C* NavPers 10057.

The professional (technical) qualifications given in appendix II are those which enlisted personnel must have to properly perform the duties of a rate within a

particular rating. In order to know specifically what is required for advancement to DM1 or DMC, you should make a careful study of the professional requirements for the rate in which you are interested. As you study these qualifications, remember that they are the minimum requirements for each rate and that the minimum requirements for each rate include all the requirements for any lower rate.

A form, the Record of Practical Factors (NavPers 760), is kept for each man in pay grades E-3 through E-6 by his supervising officer. The form is printed with both the military and the professional factors for the rating, and space is provided for entering additional factors resulting from changes to the *Quals Manual.*

When you demonstrate proficiency in a practical factor, your supervising officer will enter the date, with his initial, on NavPers 760. When you transfer, this copy of the form will be signed by the officer, inserted in the correspondence side of your enlisted service record and forwarded. In this way, a continuous record will be kept of your progress in the skills of your rating. When you have demonstrated proficiency in all the practical factors for a rate, you will be ready to advance to the next rate. It will pay you to keep a copy of NavPers 760 for your personal record so you will always know where you stand.

When you prepare for the Navy-wide examination for your rate, which is the final hurdle between you and your advancement, refer to the latest edition of *Training Publications for Advancement in Rating,* NavPers 10052. This publication is revised about once a year and lists under each separate rating the publications on the basis of which the general service examinations are constructed.

HOW TO USE THIS BOOK

Candidates for advancement in rating are required to complete any applicable training courses. At any time

after advancement, a DM2 may commence study on this Navy training course in order to qualify for DM1 and a DM1 may commence study to qualify for DMC. (This Navy training course is also the text on the basis of which correspondence courses are prepared for the DM1 and DMC ratings.)

Use the quiz at the end of each chapter as a means of checking up on what you have learned. The answers to each quiz are given in appendix I. Try to answer the questions before you look up the answers. If you are not sure of the answer to any question, study that part of the chapter again. Remember that the quiz is a device to help you learn.

The professional qualifications for advancement in the Draftsman rating have been used as a guide in the preparation of this training course. Additional information that may help you has been included.

Appendix III in the back of this book is a list of handbooks and reference volumes which you should know how to use intelligently. You will not be held accountable on any examination for the material in these books; neither you nor anyone else could be expected to commit this material to memory. But in order to do your job well, you should know where to find this material when you need it and how to apply it to a specific problem.

Drafting Standards

Military standards for engineering drawings and for illustrations for technical manuals are published with JAN–STD or MIL–STD publication numbers. Current standards are listed in the *Index of Specifications and Standards, Used by Department of the Navy, Military Index,* volume III. The *Index* is issued twice a year in April and October and cumulative monthly supplements are issued during the intervening months. Standards which currently apply to drafting are as follows:

Number	*Title*	*Date*
MIL–STD–1A	General drawing practice	23 May 58
MIL–STD–2A	Drawing sizes	22 Aug 49
MIL–STD–3A	Format for production drawings	18 Mar 54
MIL–STD–3A Change Notice 1 and 2	Format for production drawings	17 May 55
MIL–STD–4A	Format for construction drawings	4 Sep 52
MIL–STD–8A	Dimensioning and tolerancing	5 Jun 53
MIL–STD–9	Screw thread conventions and methods of specifying	15 Jun 55
MIL–STD–10A	Surface roughness, waviness, and lay	13 Oct 55
MIL–STD–12A	Abbreviations for use on drawings	11 Mar 52
MIL–STD–14A	Architectural symbols	3 Sep 54
MIL–STD–15A	Electrical and electronic symbols	1 Apr 54
MIL–STD–15A Info Notice 1	Electrical and electronic symbols	1 Jun 54
MIL–STD–15A Change Notice 1	Electrical and electronic symbols	18 Jul 55
MIL–STD–16B	Electrical and electronic reference designations	1 Jun 56
MIL–STD–17	Mechanical symbols	6 Jul 50
MIL–STD–18A	Structural symbols	12 Aug 53
JAN–STD–19	Welding symbols	13 Nov 47
MIL–STD–20	Welding terms and definitions	14 Dec 49
MIL–STD–21	Welded-joint designs, armored-tank type	20 Oct 54
MIL–STD–22A	Welded joint design	24 Oct 56
MIL–STD–23A	Nondestructive testing symbols	25 Aug 52
MIL–STD–24A	Revision of drawings	17 Nov 55
MIL–STD–25	Nomenclature and symbols for ship structure	12 Jan 56
MIL–STD–25 Change Notice 1	Nomenclature and symbols for ship structure	14 Jun 56
MIL–STD–103	Abbreviations (for electrical and electronic use)	18 May 53
MIL–STD–106	Mathematical symbols	16 Aug 51

Number	*Title*	*Date*
MIL–STD–218–2	Technical Manuals Part 2—production and procurement of artwork for technical manuals	25 Jan 54

ADDITIONAL REFERENCES

When consulting any reference material, check to be sure that you are using the most recent edition available to you. The Navy training courses are revised frequently to bring the material up to date; and new courses are added from time to time. The current *List of Training Manuals and Correspondence Courses,* NavPers 10061 (Revised), gives the titles and NavPers numbers of all available Navy training courses. This list is revised about twice a year; therefore, be sure to consult the most recent edition.

Other publications which you may check for information on available training courses include the *Naval Training Bulletin, All Hands,* and *The Naval Reservist.* A list of available enlisted correspondence courses is given in the *Catalog of Enlisted Correspondence Courses.*

QUIZ

1. Why are the ratings of petty officers in the peacetime regular Navy termed general service ratings?
2. Name the five emergency service ratings into which the Draftsman rating may be divided under mobilization conditions.
3. In general, to what work levels common to civilian drafting do the rates DM3, DM2, DM1, and DMC correspond?
4. Where may the general requirements for advancement in rating be found?
5. Where may the specific military requirements for advancement in rating be found and where are they discussed?
6. Where may the professional requirements for advancement to Draftsman 1 or C be found and where are they discussed?
7. Why should you refer to the publication *Training Courses and Publications for General Service Ratings*, NavPers 10052, when you are preparing for the Navy-wide examination for your rating?
8. Where can you find a current listing of military drafting standards?
9. Where can you find a listing of current Navy training courses?

CHAPTER 2

ADMINISTRATION

ORGANIZATION OF THE DRAFTING ROOM

Drafting in the Navy is done for such a variety of purposes and under so many difficult conditions that it is difficult to lay down any hard and fast rules about the organization of a drafting room. Many ships and other activities have billets for only one or two draftsmen, and they become a part of one of the main divisions. Before you, as a DM1 or DMC can organize and administer a drafting room effectively, you need to understand clearly what functions your men are expected to perform.

If the work is aboard a repair ship, it will probably be done in close contact with the shop and include freehand sketching, tracing, making and printing detail drawings, and layout. If the drafting room is part of a construction battalion for an advanced base, the work will include "as-built" drawings as well, and both a technical library and a reproduction room may be included. It is your responsibility as soon as you are placed in charge of a drafting room to find out exactly what functions are expected.

You should also study the men assigned to you, the rates they hold, the training and experience they have had, and their individual qualifications. If you are setting up a new organization, you will have to make imme-

diate decisions regarding assignments. If the drafting room is already in operation, you will probably not make many changes until you have had time to study the layout thoroughly, but you should be looking ahead toward possible improvements and toward giving each man a chance for advancement.

When you have clearly in mind just what is to be done and who is to do it, you are ready to tackle the problem of how it shall be done. This involves many factors, not the least of which is the physical arrangement of the space at your disposal. Don't overlook the fact that physical surroundings have a considerable effect on efficiency. How you allot the space and how you arrange the furniture and equipment should have their share of your time and thought.

Layout of the Room

Small crowded rooms hinder good work and make effective safety practices difficult. Fifty square feet of floor space per man, exclusive of storage space, is generally considered a minimum in any kind of shop work. Aboard ship it may not be possible to allot this minimum space, but at a shore station it should be. Whenever possible this should be increased. Rooms with a length to width ratio of approximately 2:1 are considered more desirable, because it is easier to arrange equipment effectively and to obtain efficient distribution of light.

Keep in mind that, if possible, drawing tables should be arranged so that the light comes from behind the man working at the table or over his left shoulder. North-side windows are best for admitting daylight in the northern hemisphere. It is important that the lighting in the room is adequate, both as to quality and intensity. However, take care to avoid placing working areas in positions where they will be subjected to the glare of direct sunlight. An important factor to consider is the conservation of vision, since excessive light, as well as inadequate light, induces severe eyestrain. Usually excellent artificial lighting is achieved by the use of portable adjustable lamps,

which can be clamped to the drawing table and moved so that the light falls in such a way as to minimize shadow and glare.

When you arrange the drafting room, try to separate work areas and storage space. Keep materials and instruments which are not in use in easily accessible cabinets, and see to it that it is not necessary for someone to walk around a man who is working in order to reach them. Keep prints where they can be reached quickly by any authorized person. Locate reproduction equipment in a separate room if possible.

Aboard ship, of course, you are likely to find many limitations necessary, besides the obvious one of space. In positioning equipment in a shipboard drafting room, keep in mind the pitch and roll of the ship and the possible effect on materials and equipment.

It is often a good idea when you plan the placement of equipment to draw up a plan of the available space to scale. Then think through the various operations from the point of view of efficiency and that of speed. When you place each piece of equipment on the plan, think how it will be used, the steps involved in its use, and the amount of noise or disturbance which may be caused.

Maintenance

Analyze the different jobs required to keep the drafting room and its equipment in shape to (1) get the job done quickly and (2) create habits of orderliness and cleanliness in the men. It is your job to assign these jobs and to see that things are kept up to snuff.

It is always important to see that equipment and instruments are kept in good condition and to impress upon the men under you this fact. Bad equipment and instruments mean inefficiency. Any draftsman worth his salt sets a high value on good work habits and care of equipment. Even a striker should have begun to feel a professional pride in keeping equipment clean and in good working order.

Organization of Personnel

If the number of draftsmen assigned to an activity is small, there is no need for an elaborate organization. Each man will have to do a variety of jobs and will usually do all the work on one drawing himself, carrying it through from its inception to its finish.

If there are a number of draftsmen and a number of different types of projects assigned, it is best to organize the men into sections. These may be simply the divisions formed by the emergency ratings, such as a mechanical section, a structural section, an electrical section, or there may be sections for special areas within these fields.

If the drafting room includes a number of rates headed by a chief, the chief may designate a DMI as a checker. If there are a number of sections, the man with the highest rate in each section may be placed in charge. In this case, the chief may give him the work assignments and instruction, and he may make most of the assignments to individuals in his section.

Your detail draftsmen need to be, primarily, good draftsmen. They must be able to select views to the best advantage and to arrange views and notes on the drawing sheet so that they are both neat and easy to interpret. Letter and line work must be neat and of a quality that will reproduce clearly. A detail draftsman must be very familiar with JAN and MIL standards, as well as with the required standards of the particular activity where he is billeted.

Assign routine tasks to specific men, usually strikers or DM3s, so that you will know just whom to hold responsible for getting a job done and who is entitled to praise or blame. Among the jobs that can be handled by men with little drafting experience are printing, tracing, and corrections after checking. Men in charge of files do not have to be expert draftsmen, but nevertheless they have a very responsible job. For efficiency in training and for the best morale, maintain enough rota-

tion to allow each man to get the experience required for advancement in rating.

This practice will also serve to prevent work stoppages because of the absence of a key man. Transfers, leave, hospitalization, and various other happenings cause frequent changes of personnel in the Navy. It is necessary at all times to be prepared for such eventualities by keeping your men trained to replace one another.

If the drafting room is large, an organization chart may serve to make its operations and the lines of authority more meaningful to the men involved, as well as to outsiders. Occasionally, a flow chart may be of value. As far as practicable, it is best to make organization charts conform to the standard format described in the *Organization Manual of the Department of the Navy*, NavExos P–861B.

Once you get an organization on paper, it is easier to see how it functions. It is also easier to see organizational weaknesses as well as strengths. Thus, the chart may serve as a basis for planning a reorganization. If a system you have devised fails to work as efficiently as you had expected, the only thing to do is to change it. It is the mark of a wide-awake supervisor that he keeps his mind open to the possible need for changes and makes them when they seem desirable instead of continuing a practice just because "it has always been done that way."

Frequent reorganization of procedures, however, usually indicates that the original planning was faulty and can be regarded as a reflection upon your abilities as a supervisor. So use your head in the beginning and save not only your feet, as the saying goes, but also your face.

Tracing and Print Files

When a filing system is established, it should be one that is adapted to the needs of the activity using it. Therefore, no hard and fast rules can be laid down on filing. The following paragraphs contain a few sugges-

tions that may be of help to you. You will have the responsibility for seeing that tracings and prints are filed in the manner best adapted to the particular needs of your activity. The efficiency of the system will depend on your judgment.

Drawing numbers are assigned to drawings by various bureaus, each bureau assigning drawing numbers to those drawings for work over which it has cognizance. The only exceptions may be drawings which have only a limited local value. Drawing numbers may be assigned in blocks to an activity, or it may be necessary for the activity to make a request to a bureau for a number for a particular drawing. Two drawings should never be given the same drawing number. If this happens in spite of all precautions, the number on one of the drawings must be changed. You may find that it is convenient to file drawings within a particular category by the drawing numbers.

Tracings are usually kept in filing cases especially made for filing drawings. Separate reference card files, one by subject and one by number, may be maintained as a record. Superseded tracings should be destroyed, but they may be kept in a separate drawer for a designated period. Classified tracings should be kept in locked files.

Tracings should be taken from the file only to be sent to the reproduction room. They should be removed from, and returned to, the file only by the man in charge, and all such movements of tracings should be noted by him on his records. Once a tracing is filed in the wrong place, it is the same as lost.

When the activity is receiving brownlines, or vandykes, from which reproductions may be made, hundreds may be received each week. In this case, it is critical that each print should be logged in and an accurate record kept of it, just as with tracings. Only up-to-date prints with the latest revisions should be kept in the files, and all out-of-date prints should be destroyed promptly.

Unreproducible prints are usually kept in a totally different place from tracings. They should be more accessible, for one thing, since they may be used more often and by other departments. Many activities prefer to keep prints in a stick file. That means that a group of prints are suspended open between two sticks and the unit placed on a stick rack for stowage. This is especially convenient if all the drawings for one project are placed on one stick.

A record of each issuance of a print should be kept, showing the date on which it was made, the name of the individual to whom the print was issued, and the department he represented. Such a record may serve to prevent considerable confusion and criticism, besides making it possible to recall out-of-date prints. Prints should be kept up to date at all times. When new prints are made or received, old versions should be destroyed, including those issued to the departments.

Technical Library

Most drafting rooms must, of necessity, have available a technical library of handbooks, naval and military publications, specifications, etc. Especially at advanced bases, this library may be intended for the use of other departments as well. The *Detailed Catalog of Yards and Docks Material for Advanced Base Functional Components*, NavDocks P–103, contains a list of the kit of technical publications, Component or Assembly 4012, which is intended as a technical library for advanced bases. Actually more publications than those listed will usually be needed.

A file of JAN and MIL standards and specifications may be kept and with it the *Index of Specifications and Standards, Used by Department of the Navy, Military Index*, volume III. With the exception of the specifications for food or clothing, most of these will be of value to the draftsman. For example, if a bearing drawing is requested, it is possible to look up in the specification the

characteristics of the metal to be used and therefore make more accurate notes on the drawing.

New books or books which are especially desired may be requested by means of a letter to the bureau which has cognizance over your activity. Most books are shipped from stocks maintained at supply centers, but authority for their issuance must be obtained first.

Books are provided, but library shelves, chairs, and other equipment are either regular ship or station furniture or they are especially constructed or obtained for the purpose. Ideally a library should be large, well-lighted, and otherwise attractive. Ideal conditions may not be possible, but you should do what you can to see that the place is made usable. Books should be arranged so that they can be seen and examined, and the place should be neat and clean.

For all collections of as many as several hundred books, it is essential to post shelf labels to indicate where the various types of books are located. Each book should be classified and marked before it is placed on a shelf. This is necessary not only to determine what shelf it belongs on but also to identify it as a library book, so that it will be easier to keep track of its whereabouts.

Identifying marks are usually made with a rubber stamp bearing the name of the ship or station. The book is stamped on the inside of the front and back covers and on the title page. When there are two or more copies of the same book, the books, as well as any file cards, should be marked to indicate this fact. It is not necessary to mark the first copy, but the second copy should be marked "copy 2," and so forth.

In order to keep track of books, it is best to keep a card file. Cards may be filed by author and title in separate files, or author and title cards may be filed together alphabetically. Plain cards, 3 by 5 inches, may be used. If possible the cards should be typed. In any case, they should be neat and uniform.

File author cards alphabetically by the author's last name. When there is more than one title by the same

author, file the cards alphabetically by title under the author's name. File title cards alphabetically by the first word in the title, omitting "a," "an," and "the." If there are several titles beginning with the same word, arrange them alphabetically by the second word.

Checking books in and out of the library requires careful attention to detail. A record should always be made of what happens to each book, and these records should be uniform. Unless this is done, it will not be possible to keep track of the books.

Reproduction Room

Regardless of the type of reproduction machine used, it should be positioned in the room in such a manner as to ensure the best possible ventilation. Its position in relation to the source of light is less important. If possible, the machine, especially if ammonia fumes are used in the developing process, should be set against an outside wall or bulkhead. If this is not possible, an exhaust tube should be used. With the ozalid process, ventilation should be as good as possible throughout the room, since the prints, even after they emerge from the machine, are saturated with ammonia fumes. Also heat is a factor to reckon with, no matter what type of machine is used.

Before the machine is operated and even before it is positioned, if it is a new one, the manufacturer's instruction book which is provided with it should be studied carefully. These instructions should always be strictly adhered to, not only for the most efficient operation of the machine but also to ensure the safety of personnel. Safety is an especially important factor in connection with the developing solutions used.

When the reproduction room is aboard ship, and there is a photographic laboratory also aboard ship, it will have a dehumidified, cooled storage area. If possible, all supplies of sensitized paper and other materials for the reproduction room should be kept in this photo supply room.

When materials are brought into the reproduction room, they should be stored in a light-tight space to preserve the sensitivity. Usually, the original containers are light-tight and it is best to keep the materials in them. It is also good practice to mark paper supplies so as to keep using the oldest stock before using newer stock.

Chemicals used in developing solutions are usually received in powder form. They should be stored like the sensitized materials in the photo supply room. Only as much developing solution as is necessary for immediate use should be mixed at any one time, since all developing solutions contain acids or form poisonous fumes which are detrimental to anyone coming in contact with them.

Ammonia is usually received in nonshatterable bottles packed with excelsior in wire containers. If the ammonia container is not of this nature, the ammonia should be transferred to a better container. The fumes from ammonia are very powerful and may temporarily blind anyone exposed to them even briefly.

Records and Correspondence

It is a good idea to maintain only as many records as you can conveniently keep up to date. A record that is not kept up to date is worse than useless. But, if you have a large section to supervise, you may need to keep a number of records and to delegate the responsibility for keeping some of them to others. Even if your section is small, you should keep a log book for drawing numbers and some sort of print record.

The LOG BOOK OF DRAWING NUMBERS usually consists of a list of numbers down the left hand side of the sheet. As each number is assigned, the title of the drawing is written on the same line. The date of the assignment and the name of the draftsman to whom the job is assigned may also be given. The log serves as a permanent record of the number given each drawing, so that there is less chance of a drawing being completed with the wrong number or of two drawings receiving

the same number. A cross index may also be kept by drawing title or subject on 3 by 5 cards. However, if the cards are not kept up to date the system will soon fall into disuse.

The PRINT RECORD has several purposes. It is a means of keeping track of prints so that out-of-date prints can be quickly located and destroyed. It is also of value as a record of work performed. It may be kept as a log in which orders for prints are recorded, along with the name of the ordering activity, the drawing number and its title, the number of prints made, and the date of delivery. This same information can be kept in a card file instead, with cards filed by drawing number or by drawing title.

A DRAFTING JOB SHEET serves as a check on work progress. The following are suggested as headings for the sheet:

Drawing No.	Title	Started	By	Completed

When you are in charge of a drafting section one of your jobs may be the drafting of letters concerning drawings, prints, and so forth to be signed by your commanding officer or officer-in-charge. In this case, you should obtain a copy of the *Navy Correspondence Manual,* SECNAVINST 5216.5, 1 November 1955. It contains not only chapters and sections on typing practice and format, but also on writing practice.

Of special interest will be the chapter on developing a communication. In this chapter, you will find a discussion of the things to consider in planning a letter, with general outlines for letters which are intended to serve various purposes. Other valuable material in this chapter consists of sections on evaluating the letter, means of referring to a previous communication, and using abbreviations.

Supply

For requesting supplies, you will use a Request for Issue or Turn-in (DD 1150). (See fig. 2–1.) The heading should be filled in as shown. An X is used before the word Issue if it is a request for issue, and before the word Turn-in if it is a turn-in. You should give the stock or part number, if you know it, the description of the article, and the quantity required. Most of the other spaces, with the exception of the space for the signature of the head of the department, can be filled in by the supply office. The person who actually draws the goods will sign in the RECEIVED BY space.

Although normal channels of supply must be used whenever possible, some of the articles used in the draft-

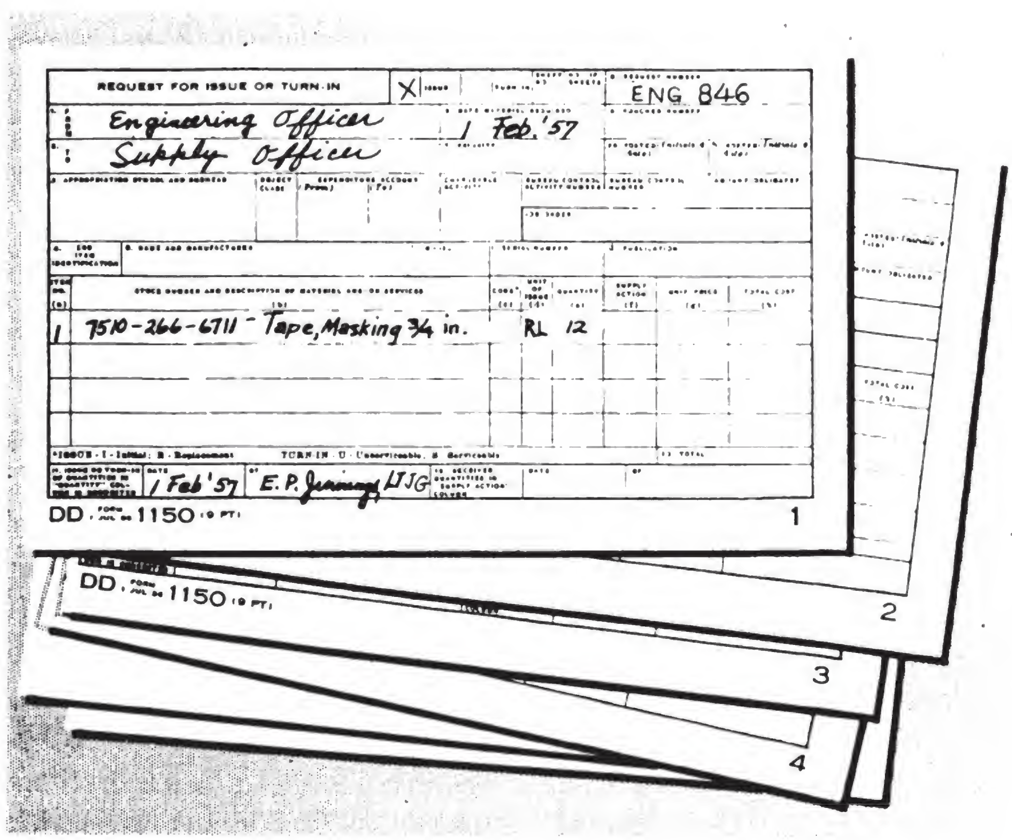


Figure 2–1.—Request for Issue or Turn-in (DD 1150).

ing room cannot be acquired directly from all supply ships or supply depots, but will have to be ordered or purchased on the open market. For this reason, you should always anticipate your needs well in advance, especially before starting on a long cruise.

If you will take a thorough inventory and prepare requisitions prior to your ship's arrival at the shore activity, the requisitions can be turned over to the local supply department upon your arrival. When this is done, the shore supply department will be in a better position to furnish the required items while your ship is still in port. This will do much to prevent a serious shortage of critical items at a later date when you are at sea far from a source of supply.

When you request articles which might have to be purchased from manufacturers or dealers, be sure to give on the form all pertinent information, such as name of article, size, name of manufacturer, number of catalog, number in catalog, etc., so that you will be assured of receiving the exact item. When a stub requisition contains items which are not ordinarily carried in stock, the stub requisition will be held unnumbered, by the supply office, until the material has been received.

Surveys

A survey is the procedure required by *Navy Regulations* when naval property must be condemned as a result of damage or deterioration, appraised because it has lost its utility, or declared nonexistent because it has been lost or stolen. The primary purpose of a survey is to provide an administrative review of the condition of the material and the cause of this condition, as well as to fix the responsibility for the condition and make a recommendation for deposition.

You may have occasion to originate a request for a survey of some item of equipment which is classified as Plant Account Material, Class 3. This class includes equipment which has a first unit cost of $100 or more and which has an expected useful life of 1 year or more.

Such equipment must not be thrown away, even though it is worn out, without a survey.

There are two types of surveys. A formal survey may be made by one commissioned officer or a board of three officers. An informal survey may be made by the department head having material to be surveyed. When the survey is approved by the commanding officer, it may be used to substantiate a request for an allotment augmentation if necessary or required for replacement of the item.

SUPERVISION

One requisite of good supervision is that the supervisor know what is going on in the office. This sounds obvious, but there are supervisors who make the mistake of thinking that when they have assigned a job, they can forget all about it until the finished work is produced. In some cases, of course, with men whose abilities and methods of working you know well, you can actually dismiss thought of a piece of work once it is assigned. A good supervisor knows which men can be relied upon to proceed on their own and which need closer supervision and direction.

If you are doing your supervisory job conscientiously, you can often prevent a mistake from being made or halt an incorrect procedure before it has gone far enough to make trouble. You can prevent your staff from forming bad habits and at the same time teach them good ones. Just the fact that you are paying attention to what they do has a salutary affect on the atmosphere in the office.

Be careful, however, how you supervise. It's a curious thing that while most of us like to feel that our seniors know what is going on, we strongly resent the sense that someone is watching our every move. We especially resent being watched if we think the watcher is constantly looking for something to complain about.

One common mistake is to do a great deal of observing but apply very little thought to what is observed. An excellent supervisor often gets more out of a brief, casual visit than another would get from standing around an

hour watching the man at work. This is because he makes a practice of knowing as much as possible about each man and, when he is near him, he really concentrates on what the man is doing and how he is doing it. He usually adopts a casual manner to save the man from embarrassment, but there is nothing casual or careless about the supervision he is exercising.

Another mistake is in being so quick to offer adverse criticism that, whenever you are around, men expect trouble. This type of supervision creates hostility and stirs up such an atmosphere of nervous apprehension that it actually causes mistakes which otherwise would not have occurred. People do their best work when they feel that the supervisor trusts and respects them and that he is present mainly to give them help and needed direction.

Of course, supervisors must criticize what the men under them are doing, but there are ways and ways of criticizing. Before you offer an adverse criticism, always make sure that you have the whole picture. It never hurts to ask a few questions before you comment. The answers may change the nature of your remarks considerably. Again, it is a good idea to keep the situation as casual as possible and avoid an attitude of accusation unless you are certain that you have reason to accuse.

Avoid, if possible, the type of criticism which merely condemns. Even if you see one of your men doing something entirely wrong, your purpose is not merely to stop him but, at the same time, to start him doing the thing right. So instead of saying, "Don't do that;" say, "This is the way to do it," or better still, "Wouldn't this be a better way?"

Most workers mean to do their jobs well most of the time. If you start with this assumption, you will find that you have ranged yourself on the side of the worker rather than against him. If you take it for granted that he means to do well and you can offer him help in doing better, there is no need for him to fear you or feel antagonism toward you. Don't make the mistake of try-

ing to explain this to the man. Just adopt a spirit of helpfulness as your fundamental attitude and make it a basis of your comments and actions. Most men will sense your attitude and respond to it.

When you have given criticism, you should carry through to see that your directions are being followed. Again, don't be too fussy or obtrusive about it, but be sure that you do the necessary checking. Expect cooperation from your men. Usually that expectation on your part will be enough to ensure compliance with your instructions, but if you find that your directions have been disregarded, take action promptly.

Even more important than knowing how and when to deliver adverse criticism is the art of giving praise and encouragement. One valuable way to encourage people is to listen to their suggestions for improvement and to ask them from time to time for their opinions on specific problems.

If you use an idea that originated with one of your men, be sure that your seniors learn that it was his idea. Don't succumb to the temptation to take the credit yourself. Even if you added something to the man's original suggstion, it is better to give him the credit. If your men are taking sufficient interest in their work to offer useful suggestions, your seniors will credit you in turn with a good job as a supervisor.

If you can let a man try out his ideas without slowing or affecting the accuracy of important projects, this course is often useful. Whether the experiment is a success or a failure, the man will have learned something. Moreover, he will realize that you are open-minded and when you do have to veto one of his suggestions, he will accept your decision with better grace.

If you really like people, you will enjoy seeing them progress. The small type of mind, the kind that is afraid to trust its own powers, has to keep other people under. On the other hand, most of the world's great men have had pupils who surpassed them in some respect. A real

leader is always glad to help others develop their abilities.

Assigning Work

One of the most important functions you will have is that of assigning the work to men who can do it. In order to be able to do this, you must understand the work; you must know exactly what you are asking a man to do and how it should be done. You must also know the man.

A man may be good at one thing and not at another. He may be able to work well on a project that requires cooperation with other men, or he may work best alone. All of these things, the varied aspects of his personality and character, should be taken into consideration in assigning the work.

As a DM1 or DMC, the chances are that you will have had experience with most of the work that is done in a Navy drafting room. At one time or another, you will have had to sit down and do a drawing like the one you will be assigning to a man under you. Or if you haven't had the experience yourself, you probably sat beside a man who did, and if you were alert to your opportunities, you profited by his experience.

But there is more to it than that. You must learn, in any administrative position, to be able to think through the job without ever actually putting anything on paper. You must be able to foresee all the steps necessary to do the job in order to make sure that (1) you get all the information needed for the job from the officer who requests it and (2) you can pass this on to the man to whom you assign the job.

Suppose that an officer calls you in and gives you a sketch which is to be made up as a finished drawing. Don't try to impress him with your eagerness. Study the sketch carefully. Jot down information on the title, scale, use, etc. Check to be sure that all the pertinent dimensions are indicated and that all information needed to make the object is available. The draftsman must always

do more than make a drawing; he must be prepared to think through the manufacturing or construction process as well.

Ask all the questions you can think of at the first interview. It is better to take a chance on being considered slightly below par mentally at this stage than to have to go back later several times with questions which you should have been able to foresee.

The next step is the actual assignment. This step often includes on-the-job training. If a man has not done the type of work before, you must explain every step to him if you want the job done well. Be sure that you explain the purpose of the job, the steps by which it may be accomplished, and all pertinent details.

Training Your Staff

Your first responsibility in training your men is to learn how much each understands about his job. If he is not trained, you or the petty officers under you must train him as quickly as possible. If he is partly trained, you should see that he gets the necessary instructions and experiences to round out his knowledge and skills. You should provide him with the appropriate training manuals and supplementary courses, and you should give him opportunities for practice.

Adopt the principle that every billet is the stage in training for a more responsible one. Applied to your own career and to those of your men, this principle will encourage continued study and efforts to improve. The *Manual for Navy Instructors,* NavPers 16103-B, contains some valuable hints on training that can be adapted for use in an in-service situation.

Checking

Checking is one of the most important jobs in the drafting rooms. It is the responsibility of the petty officer in charge, but he may delegate it to the second in command. A checker should be thoroughly familiar with

both drafting standards and shop practices, and he should be a person who is able to concentrate and has a high regard for thoroughness. A thorough job of checking may easily take considerable time. If a checker is very thorough, the man in charge may need to give only a cursory check, but since he must sign his name on the drawing before he turns it in to the officer-in-charge, he had better be sure that it has been thoroughly checked.

When a detail drawing is assigned, the DM may be given a sketch indicating the type of drawing required and the views to be shown, or he may be given a layout. If the drawing is to be made from a layout, the layout should be checked before the drawing is started to be certain that the part has been properly designed and that the best materials and best method of manufacture or of construction have been determined. Too often this is not done, and errors are discovered when the detail drawing is almost completed.

When a drawing is to be checked, a print of the drawing is usually made. On this print, the checker can note the corrections. Thus the original drawing does not have to be marked up or handled excessively. When the DM has made the corrections on the original, the checker can compare it with the check print to be sure that all of the corrections have been made. If there are further errors, the checker can use a different color of pencil to indicate them on the print or a new print can be made from the original.

In order to do a thorough job of checking, a definite sequence of procedures and a checklist of points are advisable. The following checking procedure, though most applicable to mechanical drawings, may with few alterations be applied to any type of drawing.

First ask yourself whether the drawing fits in the over-all pattern. For example:

1. Will the drawing reproduce? Will it be possible to make prints or other copies from it?

2. Are the line weights such that they will reproduce well?

3. Does it meet MIL–STD requirements for format? Is the drawing size correct? Are the headings and boxes properly placed?

4. Has proper reference been made to other drawings?

5. Does the drawing carry the correct drawing number?

Then ask yourself whether the proper methods of representing the object have been used and if the drawing shows the job and how it is to be done properly.

1. Is the method of projection the proper one for the job?

2. Are the views adequate to clearly show all the information necessary and are they arranged properly?

3. Are sectional views constructed correctly and is the section lining correct?

4. Are the line conventions and symbols consistent with JAN and MIL–STD requirements?

5. Is the proper drawing scale used? Also is that scale properly indicated on the drawing?

6. Is the drawing drawn to scale? When a drawing has been revised it may no longer be to scale, but this should be indicated by an underlined dimension and a note in the revision block.

7. Do the dimensions agree with the original layout or information?

8. Do the dimensions agree with corresponding dimensions on adjacent parts?

9. When the dimensions carry tolerances, are the tolerances correct to give proper manufacturing tolerances and allowance for fits?

10. Are the dimensions properly indicated so that the man using the drawing will need to do an absolute minimum of addition and subtraction?

11. Are there enough dimensions shown so that the job can be done? Note also that dimensions should not be repeated unnecessarily, because there is the danger of one being revised, while the other is left unchanged.

12. Are all necessary explanatory notes given and are they properly placed?

13. Are all figures and letters properly formed?
14. Are standard terminology and standard abbreviations used?
15. Is the kind of material of each part specified?
16. Are the numbers required of each part given?
17. Is the finish specified where it is needed?

When you are checking castings or machine parts, refer to a handbook for further points to check.

Revisions

Revisions of drawings are made only when someone in authority has requested them. If when the drawing is used, something proves to be incorrect, or if improvements are suggested, a drawing will usually be revised. Revisions must always be properly indicated in accordance with MIL–STD 24.

The real purpose of the change column is to show how the drawing appeared before it was revised. For example, suppose that a dimension was 2 inches and is changed to 3 inches. The change column should carry the old dimension, rather than a new one, because the new dimension will appear on the drawing. Also if something is added to the drawing, a note should be made of the addition. The revision block serves as a means of recording experience.

When it is necessary to make erasures on the original drawing, turn the paper over and erase on the back of the sheet. This has two purposes. First, dirt may have collected on the ridges formed where lines have been drawn on the face of the drawing and this dirt can be removed by erasing. If the dirt is left on the drawing, it will print, even though the line has been erased on the face of the drawing. Second, the pressure of the eraser on the ridge bends the surface back into place, eliminating the old indentation and preparing the surface of the face of the drawing to receive new lines.

When an erasure is made on the face of the drawing, it must be checked to be sure that something besides the area to be revised has not been erased accidentally. This

may happen even when an erasing shield is used. Anything erased by accident must be replaced.

When a revision is made, the style of the original drawing should be matched as closely as possible. For example, slanted letters should never be added to a line of vertical lettering, and line weights should be as close to the original line weights as possible.

Ordinarily, it is not necessary to change the lines of a drawing if a dimension is merely being changed. In this case, the old dimension is noted in the change column, and the new dimension is underlined to show that the line it refers to is not to scale.

QUIZ

1. What publication describes the standard Navy format for organization charts?
2. What must be done if the same drawing number is assigned to two different drawings?
3. Where are classified tracings kept?
4. What should be done with out-of-date prints?
5. What is the most important consideration when a reproduction machine is to be placed in a room?
6. Name two reasons why the manufacturer's instructions for the use of a reproduction machine should be strictly adhered to.
7. In what type of area is it best to keep supplies of sensitized paper and other materials for the reproduction room?
8. When reproduction materials are stored in the reproduction room what type of space should be used?
9. How much developing solution should be prepared at any one time? Why?
10. If ammonia is not in a nonshatterable container, what should be done with it?
11. When someone is exposed to ammonia fumes even temporarily, what may happen?
12. What publication should you refer to if you are composing a letter for the signature of your commanding officer or officer-in-charge?
13. When is a supply survey used?
14. Why are a definite sequence of checking procedure and a checklist of points advisable?
15. When are revisions of drawings made?

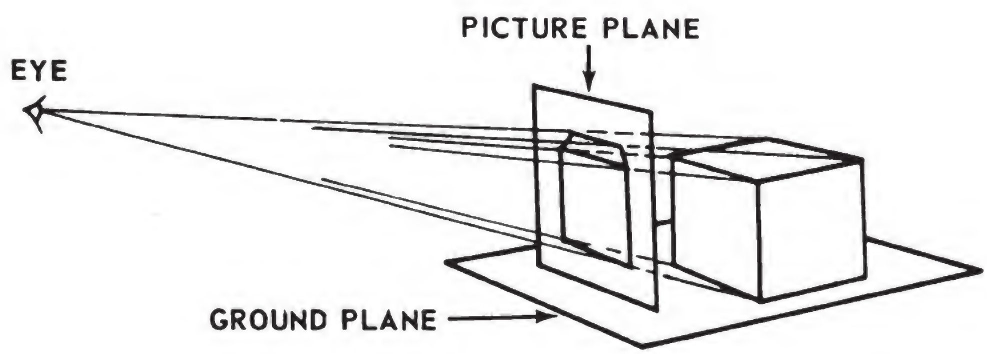
CHAPTER 3

AUXILIARY VIEWS AND PERSPECTIVE DRAWINGS

THEORY OF PROJECTIONS

Projection is the method for reproducing three-dimensional objects in a recognizable form on a flat plane. The projections in use in engineering drafting may be classified as central, or perspective, projection and parallel projection.

In perspective projection, the projection lines converge from the object to a central, or station, point. This is illustrated in figure 3–1. In the figure, an eye is drawn looking through a transparent plane, called a picture



Courtesy Delmar Publishers, Inc.

Figure 3–1.—Central or perspective projection.

plane, at a cube. The projectors are drawn from the corners of the cube and converge at the eye, which represents the station point. When the piercing points on the plane of projection, or picture plane, are connected by lines, a perspective drawing results. The picture plane might be placed behind the object, instead of in front of it. In this case, the perspective drawing would be larger than the object.

Perspective projections are one-view projections, and as you can see, they show how an object will look to an observer. However, since the receding planes are foreshortened, they do not show the shape or the dimensions of these planes.

Parallel projection differs from perspective projection in that the projectors instead of converging are kept parallel. The resulting image on the plane of projection does not resemble the object as it would be seen by an observer.

Parallel projection in turn may be divided into two classifications: oblique projection and orthographic projection. In oblique projection, the projectors remain parallel but pass through the picture plane at an oblique angle to it. Examples of oblique projection are shown in the upper left hand corner of figure 3–2.

Note that in the upper figures, the faces remain parallelograms but are not projected in their true sizes and shapes. In other words, an oblique projection shows lines and figures which are parallel to the plane of projection in their true sizes and shapes. But lines which are perpendicular to the plane of projection may be shown in any desired direction and of any desired length depending on the direction of the parallel projectors.

Oblique projections, like perspective projections, are single-view projections. Orthographic projections, on the other hand, may be either single-view or multiview. In order to show more than one face of a cube when the projectors are perpendicular to the plane of projection, it is necessary either to turn the cube so that its faces are

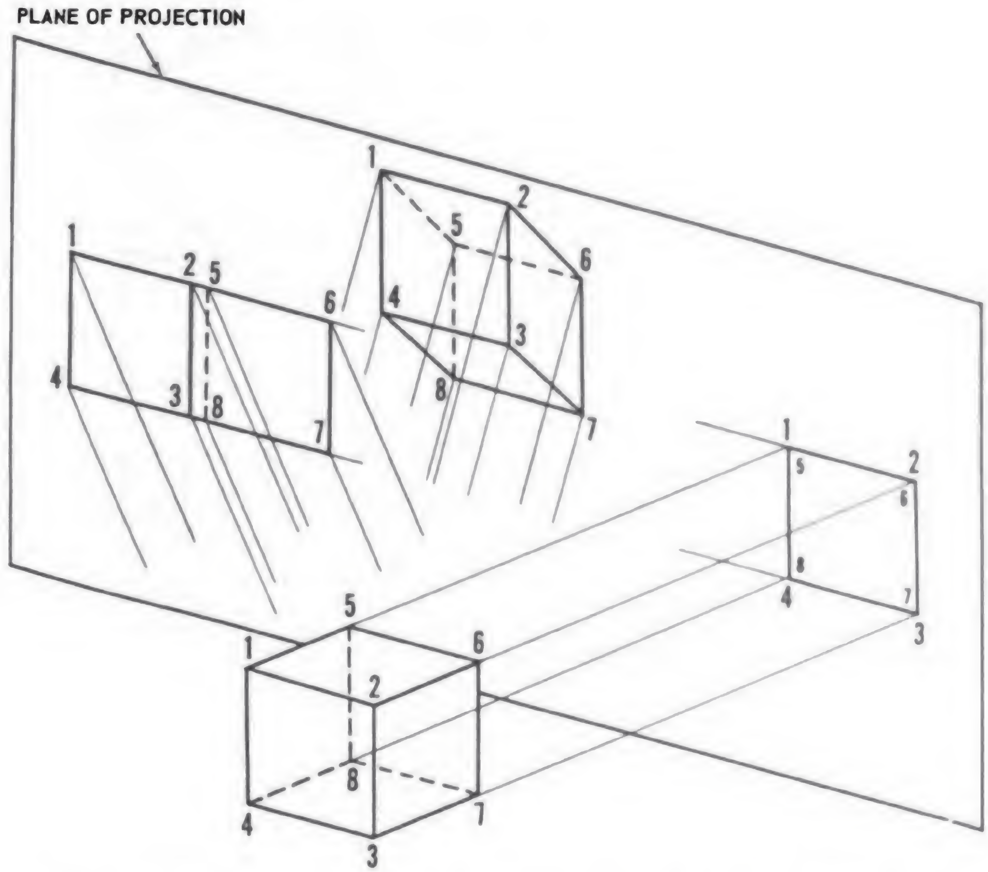


Figure 3–2.—Oblique projections and orthographic projection of one side.

inclined to the plane of projection or to show additional views on additional planes of projection.

Single-view projections which may be classified as orthographic because their projectors are perpendicular to the planes of projection are called axonometric. In axonometric projection, the faces of the object are inclined to the plane of projection.

In figure 3–3, a cube is shown in axonometric projection. The three edges of the cube meeting at the corner, marked 2 in figure 3–3, are considered the co-ordinate axes on which the projection can be measured. This is what gives the projection its name.

Axonometric projections may be isometric, dimetric, or trimetric, depending on the number of scales of reduction

required. In isometric projection, the same scale may be used for all three sides. In dimetric, two sides are the same, but a different scale must be used for the third side. In trimetric, three different scales must be used, one for each side.

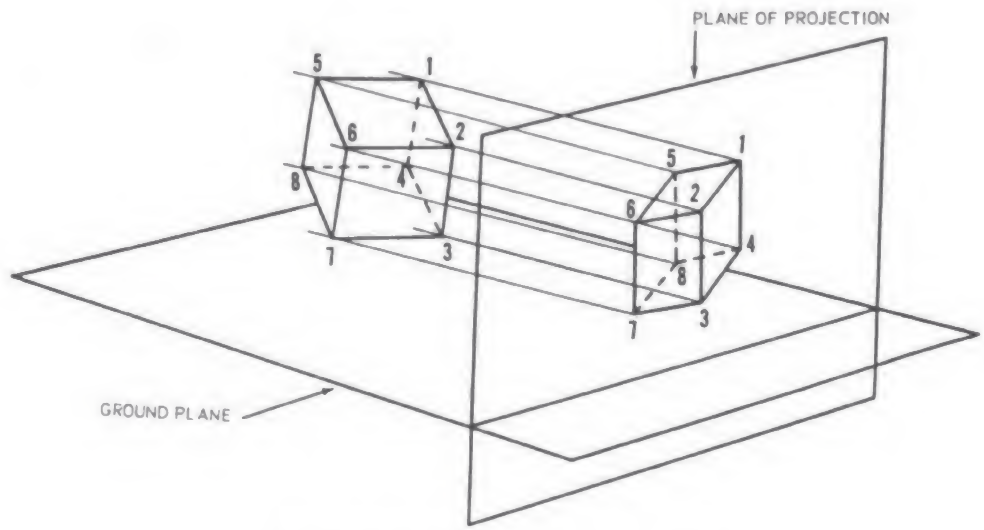


Figure 3–3.—Axonometric projection.

Isometric projection involves a reduction of scale. Since the faces of the object are considered as inclined to the plane of projection, a certain amount of foreshortening is inevitable. To avoid this scale reduction, isometric drawings are made instead of isometric projections. Figure 3–4 shows a comparison of an isometric projection of a cube and an isometric drawing of the same cube. Note that all the planes are slightly distorted in both isometric projection and isometric drawing.

Multiview orthographic projection may in theory be first, second, third, or fourth angle. That is, the object may be considered as placed in any one of four quadrants formed by three planes of projection. (See fig. 3–5.) Actually, for technical reasons, the second and fourth angle are not used. In practice in this country, only third-angle projection is used. However, first-angle projection is used in almost all European countries, and you may

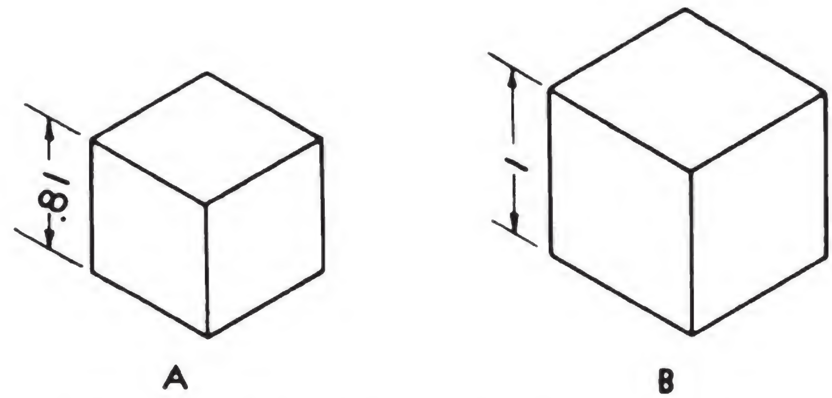


Figure 3–4.—A. Isometric projection. B. Isometric drawing.

be called on at some time to read a drawing made by this method. If you keep in mind that the position of the views is different, this will not be as difficult. Figure 3–6A shows a cube in position in the first angle of the quadrant, and figure 3–6B shows the revolved position

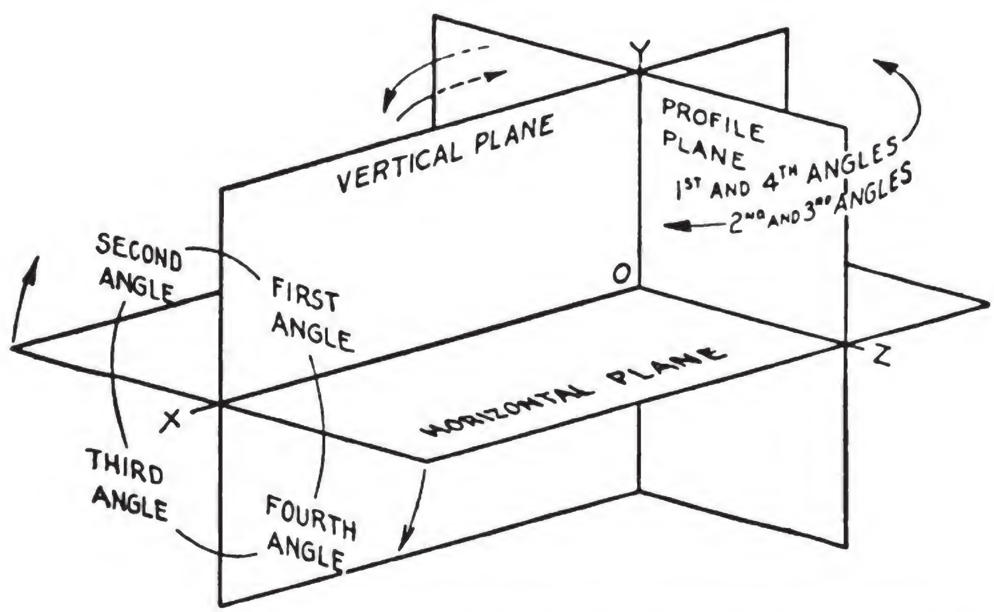


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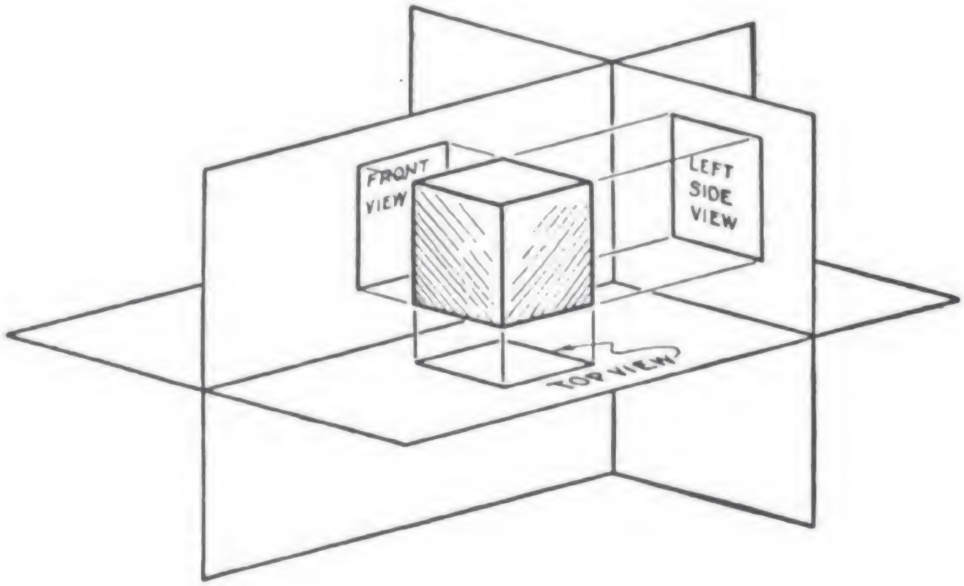
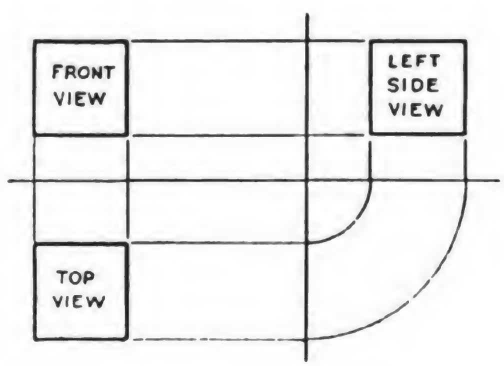
Figure 3–5.—Planes of projection.

of the planes in first-angle projection. Figure 3–7 shows the position of the object in third-angle projection and the revolved position of the planes.



A



B

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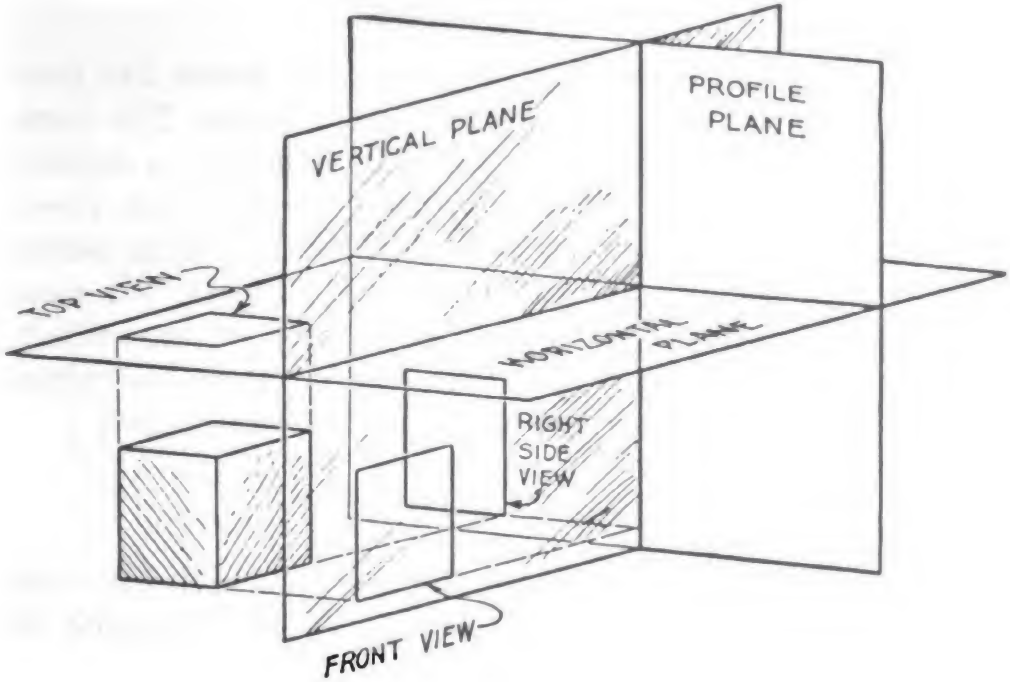
Figure 3–6.—A. First angle projection. B. Revolved position of planes.



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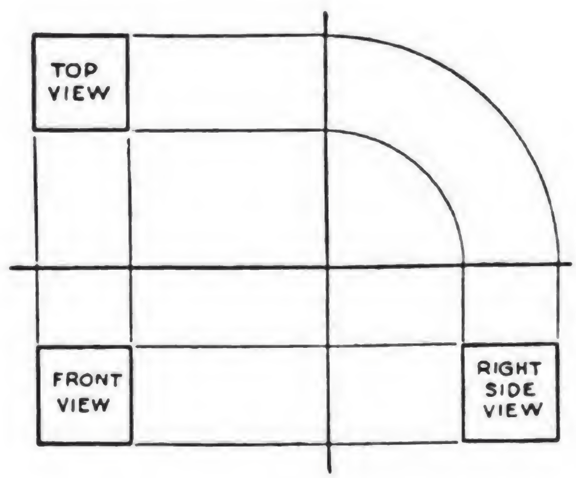

B

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Figure 3–7.—A. Third-angle projection. B. Revolved position of planes.

AUXILIARY VIEWS

In third-angle orthographic projection, views are projected onto planes which are parallel to them. The common views can be projected on the planes of a square box. There is a front view, two side views, a top view, a bottom view, and a back view. In practice, three views are usually sufficient to describe most objects. An auxiliary view may be used when a surface on the object is inclined to as much as two of these views or when the surface is inclined to all of the principal views.

Primary Auxiliary Views

In the first case, the auxiliary plane on which the view is projected is considered to be hinged to the plane of the view to which it is perpendicular. This may be a front view, a top view, or a side view. And it will be hinged at the angle of inclination of the plane of the auxiliary view on the object. That is, it may be hinged at any angle between the other principal views and will fall between them. (See fig. 3–8.)

The chief purpose of an auxiliary view is to show the inclined plane on the object in its true shape and dimensions. As you can see in figure 3–9, the shape of the object in the auxiliary view is derived from the principal views by drawing projection lines from them. Figure 3–9 shows a frontal auxiliary view projected on a frontal auxiliary plane, but the same method would be used with other views.

Notice that only the inclined portion of the object is shown in the auxiliary view in figure 3–9. This is common practice, since true shape and dimensions would not be shown for the rest of the object. In other words, this is a partial auxiliary view, but a partial auxiliary view is all that is needed.

Auxiliary views may also have another use on mechanical drawings. They may be used to aid in the construction of foreshortened principal views. Especially where the foreshortened views include noncircular curves,

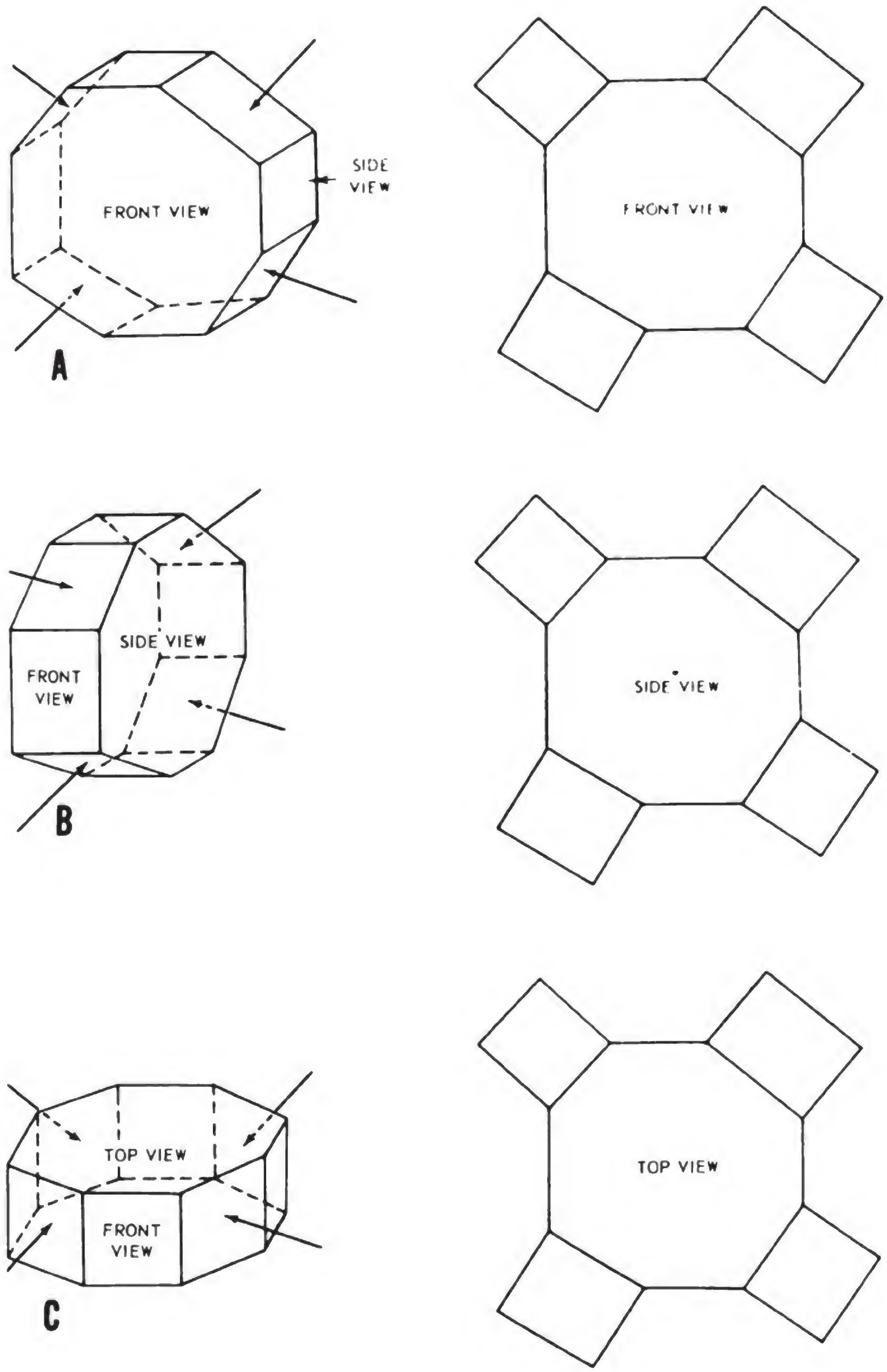

Figure 3-8.—Locations for auxiliary planes. A. Hinged to the frontal plane of projection. B. Hinged to a side plane. C. Hinged to the top plane.

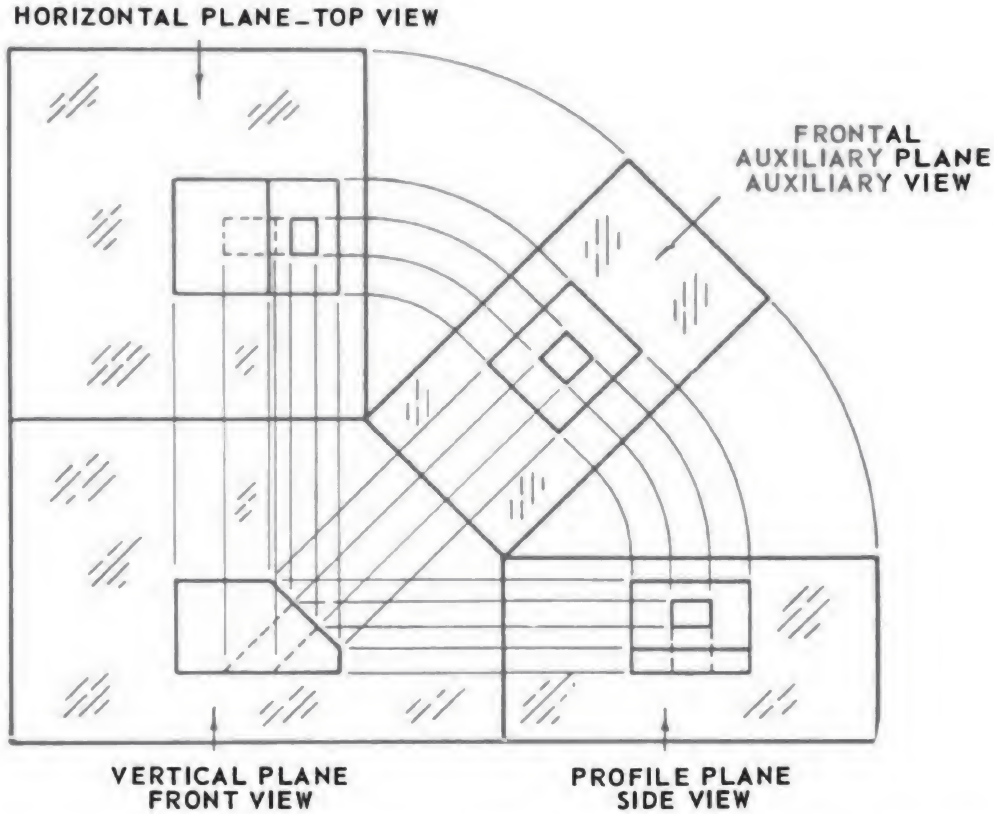

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Figure 3–9.—Use of projection lines in locating an auxiliary view.

the principal view cannot be completed until the auxiliary view has been drawn.

The shaft guide drawing in figure 3–10 shows three views—a front view, a frontal auxiliary view of an inclined surface, and a top view. In order to complete the top view, it is necessary to draw the auxiliary view. There is a hole bored through the guide at an angle of 30° and with a diameter of 1¼ inches. In the top view, the ends of this hole will be elliptical and the ends of the part through which it is bored will be semielliptical. In order to construct these curves, a series of points must be plotted. The intersections of lines projected from the auxiliary view with lines projected from the front view locate these points.

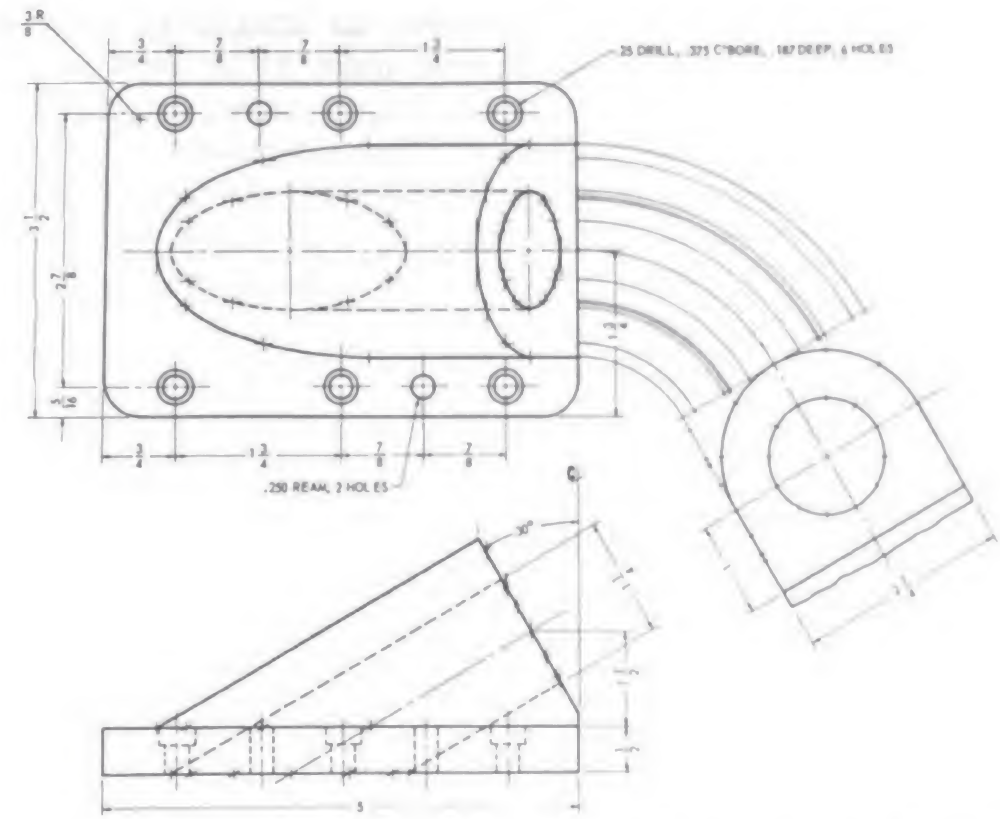

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Figure 3–10.—Use of auxiliary view to aid in construction of foreshortened principal view.

The method of making these construction lines is similar to the methods described in *Draftsman 2*, NavPers 10473, for projecting the length of elements to the development of an object. The circle and semicircle in the auxiliary view are divided into equal segments. Twelve division points are located on the circle and seven on the semicircle. A line is projected from each of the points in the auxiliary view to locate these points in the front view. The location of the points are then projected from both the front view and the auxiliary view to the top view. Notice that the intersection marked by *C* in the drawing is used as the center for drawing the arcs from the auxiliary view to the top view.

Instead of projecting lines in order to find the proper width of a surface in another view, an imaginary plane, called a reference plane, may be used. It is used particularly when it is not convenient to draw projection lines between the top, auxiliary, and side views.

The reference plane may be placed in any convenient position. On a symmetrical object, it may be in the center, as shown in figure 3–11. The edge of this plane appears as a straight line in the top view, side view, and auxiliary view. All that is needed in order to keep the proper width is to measure the dimensions of *A* and *B* in each of these views. Since the views are symmetrical, the measurements of *A* and *B* on each side of the reference plane will be the same.

The plane may also be placed against the front surface, as shown in figure 3–12A, or against an inner surface, as shown in figure 3–12B. When all the dimensions are measured on one side of the reference line, the views are

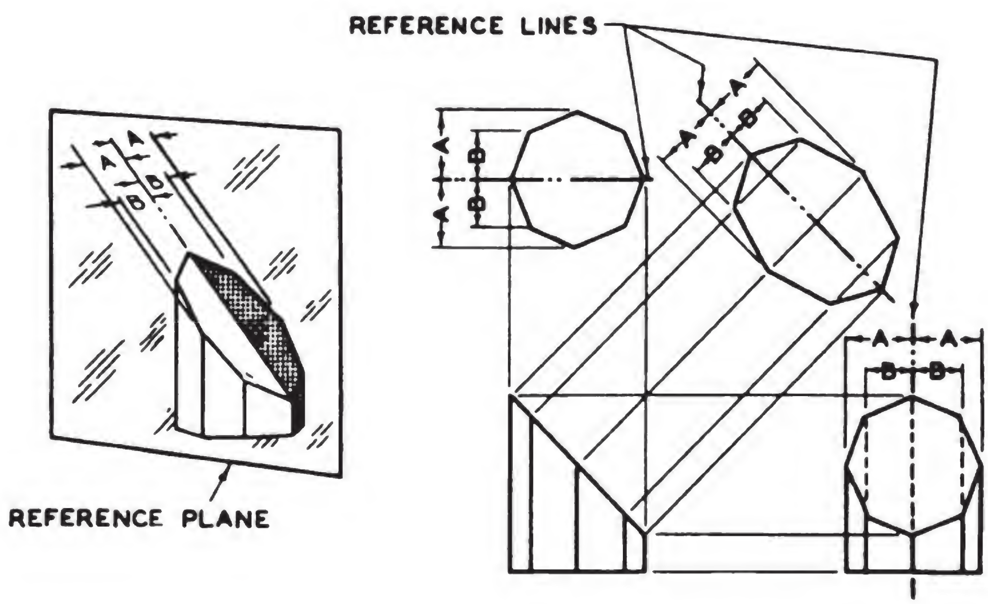

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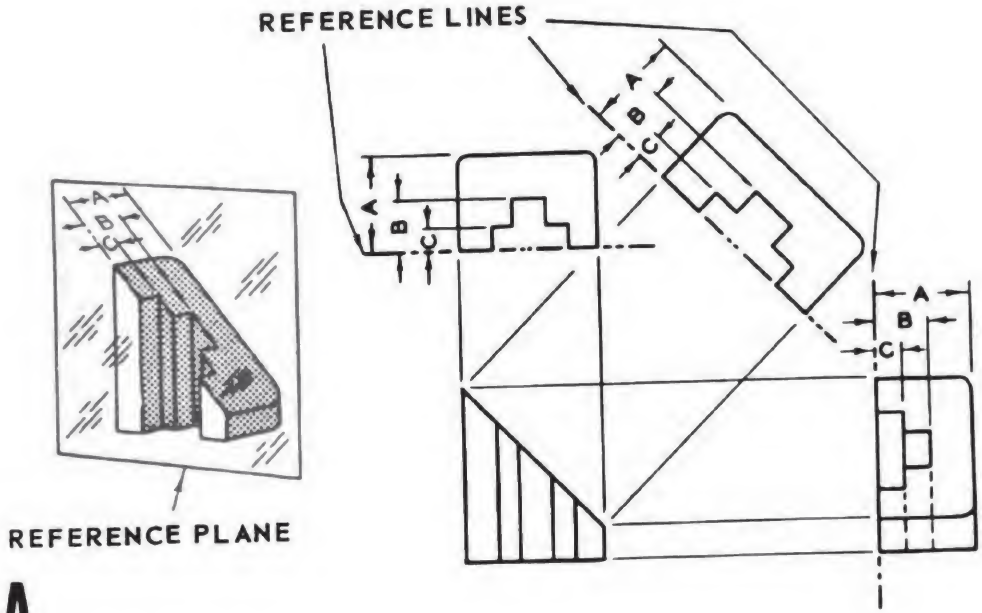
Figure 3–11.—Use of a reference plane on a symmetrical object.



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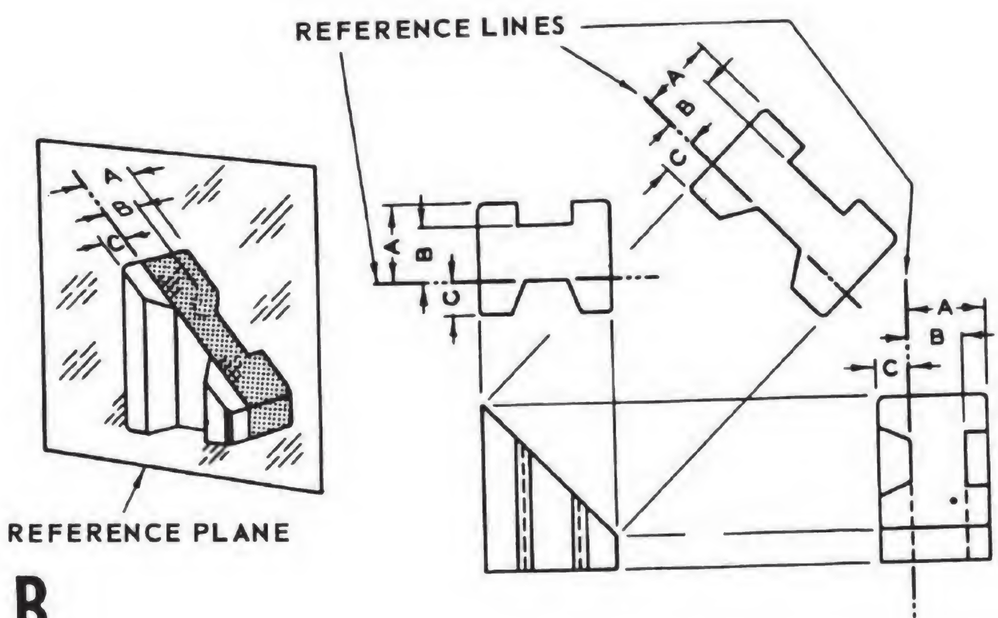

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Figure 3–12.—Use of reference planes. A. Against a front surface. B. Against an inner surface.

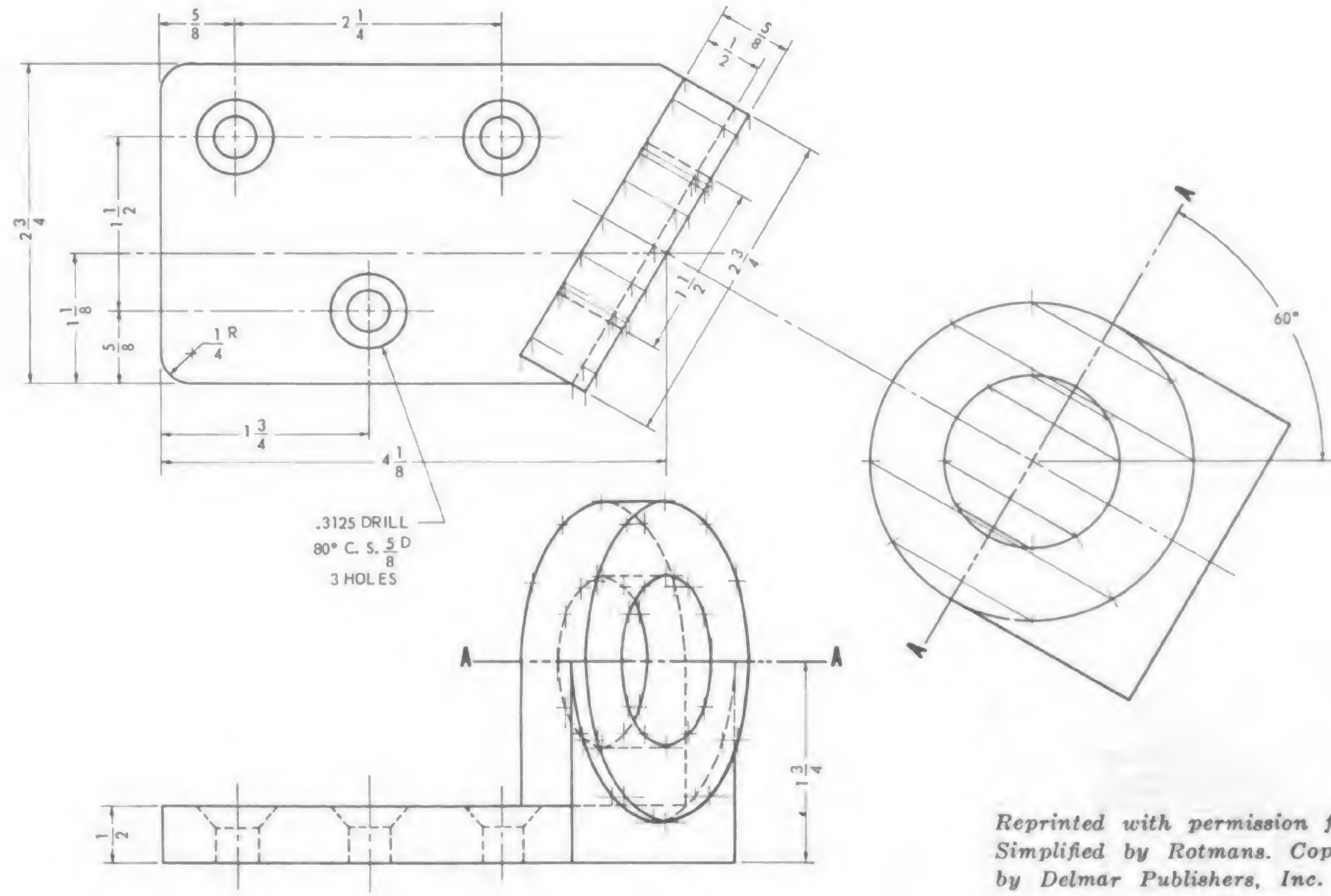

Figure 3–13.—Use of a horizontal reference plane in a top auxiliary view.

called unilateral views. When some of the dimensions are measured on one side of the line and unequal dimensions are measured on the other, as shown in figure 3–12B, the views are called bilateral views.

The reference plane for other than frontal auxiliary views may be horizontal, instead of vertical. For example, in figure 3–13, a horizontal reference plane has been used in a top auxiliary view. In order to draw the ellipses in the front view, the circles in the auxiliary view have been divided into 12 equal parts. The points thus found are projected to the top view and then down to the front view. Since the auxiliary view and the front view have a common height, the measurements may be transferred from the reference line on the auxiliary view to the proper line on the front view.

Secondary Auxiliary Views

When primary auxiliary views are drawn, the auxiliary plane is hinged to one of the principal planes. Sometimes, however, a surface on the object is inclined to the surfaces of all the principal views. When this is true, first a primary auxiliary view must be drawn and then a secondary auxiliary view on a plane hinged to the plane of the primary auxiliary view. Sometimes these are called double auxiliary views. The plane on which the secondary auxiliary view is projected may be called the oblique auxiliary plane. (See fig. 3–14.)

The height of the secondary auxiliary view is the same as the height of the oblique surface on the object. And this is shown in its true height as the inclined plane on the primary auxiliary view. Therefore, lines may be projected from this plane in the primary auxiliary view to the secondary auxiliary view to give the true height of the plane. (See fig. 3–14.)

Notice that the length of the oblique surface on the object is the same in the top view as in the secondary auxiliary view. Lines may be projected from the top view to obtain the length of the secondary auxiliary view.

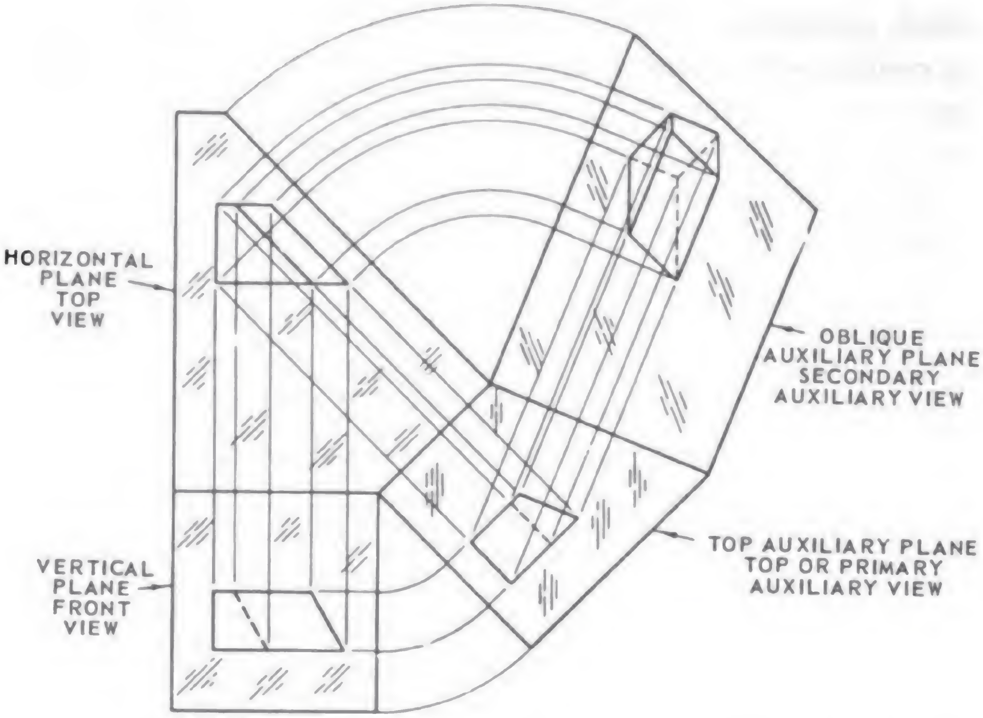

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Figure 3–14.—Secondary (double) auxiliary view.

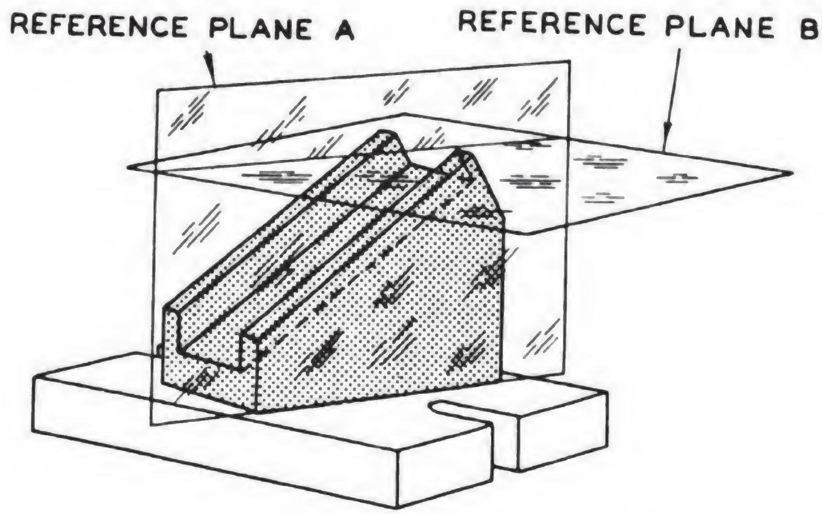

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Figure 3–15.—Tool grinding fixture with reference planes.

The double auxiliary views may be drawn by using reference planes instead of projection planes. Figure 3–15 shows a tool grinding fixture with an oblique surface on which both a vertical and a horizontal reference plane are used. The horizontal plane is labeled *B*, and the vertical plane *A*.

In figure 3–16, the double auxiliary views of the tool grinding fixture have been drawn. In this drawing, 2 secondary auxiliary views were necessary to describe the 2 oblique surfaces on the fixture. Since the top view and both the secondary auxiliary views have a common width, measurements were made from the vertical reference plane *A*. Since the front view and the primary auxiliary view have a common height, measurements were made from the horizontal reference plane *B*. Lines were projected from the top view to the primary auxiliary view to complete it and from the primary auxiliary view to the two secondary auxiliary views to complete the drawing. Notice that all three of the auxiliary views are partial views.

Revolution

Revolution is used to obtain the same results as auxiliary views. In revolution, the object is revolved in a principal view until the inclined surface on it is parallel to another principal view.

In figure 3–17, a comparison is made of the two methods. In the drawing at the left, the block is drawn in its normal position in the front view and a frontal auxiliary view is drawn in a position perpendicular to the line of the inclined surface on the block. In the drawing on the right, the view of the block has been revolved without changing the shape or dimensions of the view. The line of the inclined surface is now perpendicular to the side view. This means that the inclined surface can be shown in its true shape and dimensions in the side view and no auxiliary view is necessary.

In the revolution method, the object is revolved around a point which represents the axis of revolution. In figure

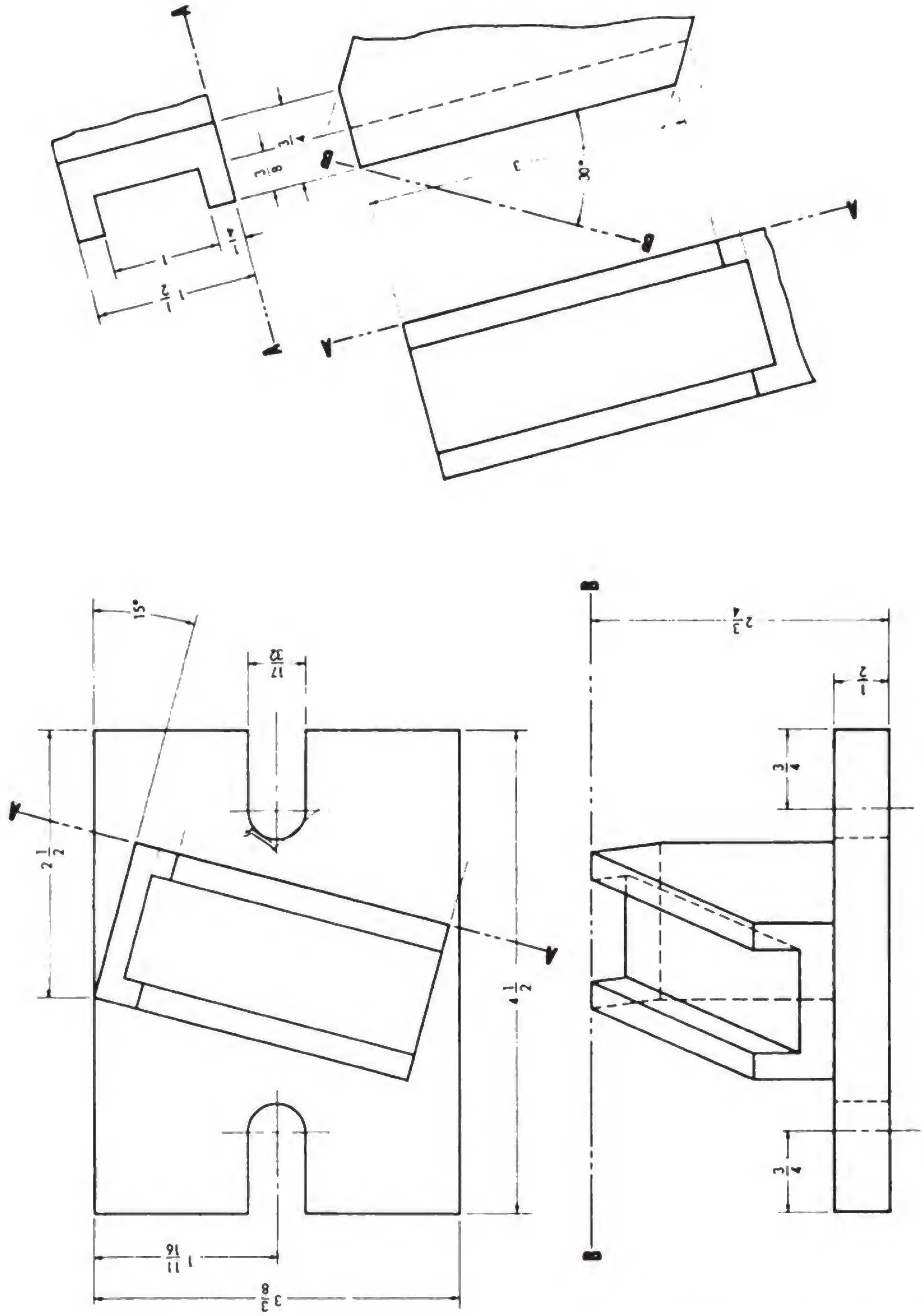

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Figure 3–16.—Drawing with two secondary auxiliary views.

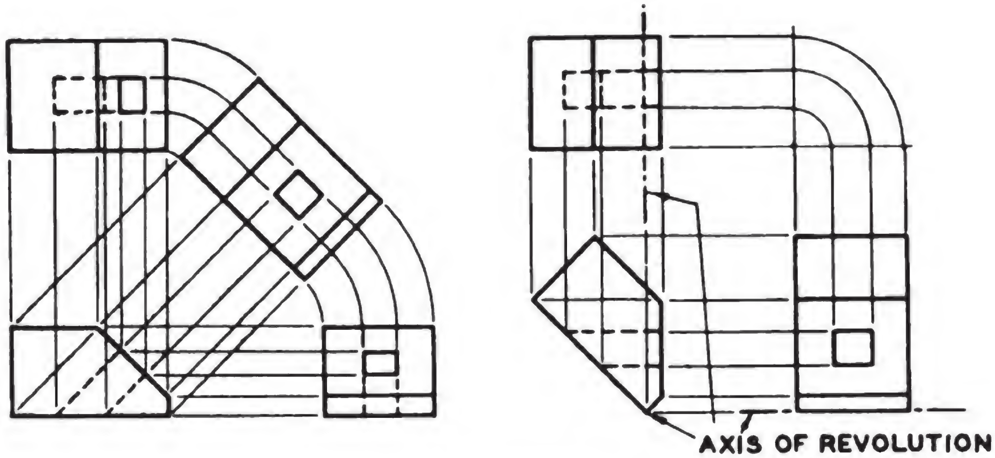

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Figure 3–17.—Comparison of auxiliary and revolution methods.

3–17, the axis of revolution is perpendicular to the frontal plane and parallel to the horizontal and profile planes. It appears as a point in the front view and as a line in the top and side views.

Revolution may also be used to aid in the construction of principal views. Figure 3–18 shows the same pump mounting that was drawn with an auxiliary view in figure 3–13. First, the part containing the large hole was drawn in a simple front view with the base of the mounting omitted. Then the top view of this part was drawn. The circles in the front view were divided into 12 parts and lines were projected from these division points to the top view.

Next the top view was simply revolved 60° about the partial axis of revolution labeled *A* in the drawing and drawn in this position attached to the base. The points in the top view were transferred by means of dividers to the new position. In order to complete the drawing of the complete pump mounting, lines were projected from these points downward, and from the circles in the original front view, lines were projected to the right. The intersection of these lines located the points on the elliptical curves in the final drawing.

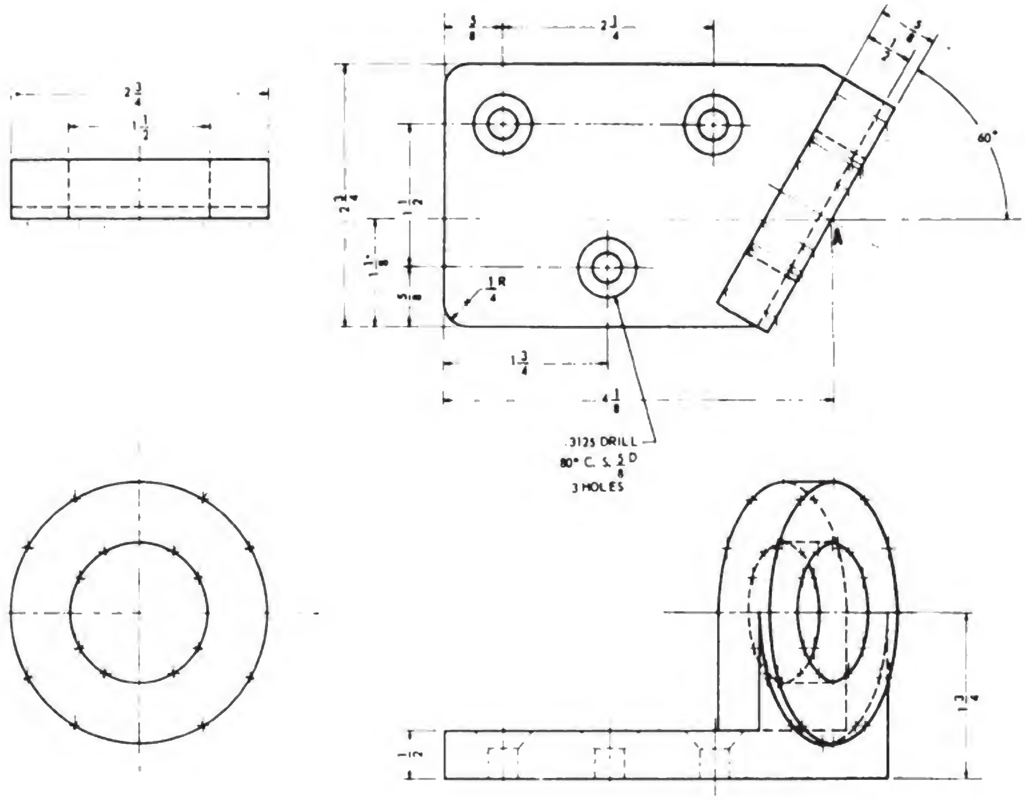

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Figure 3–18.—Use of revolution to aid in completing a principal view.

In this drawing, the revolution is around a vertical axis rather than an axis perpendicular to the frontal plane. The axis of revolution may also be made perpendicular to the profile plane, depending upon the position of the inclined surface on the object.

Occasionally, a simple revolution with a single axis is not sufficient for a complete description of the object. In this case, the object may be revolved about an axis and then revolved again about another axis, in what is called successive revolution. Successive revolution compares with the use of the double auxiliary view. (See fig. 3–19.)

In figure 3–19A, a primary top auxiliary view is projected from the top view, and a secondary auxiliary

view is projected from the primary auxiliary view. The secondary auxiliary view shows the true shape of the oblique surface on the object.

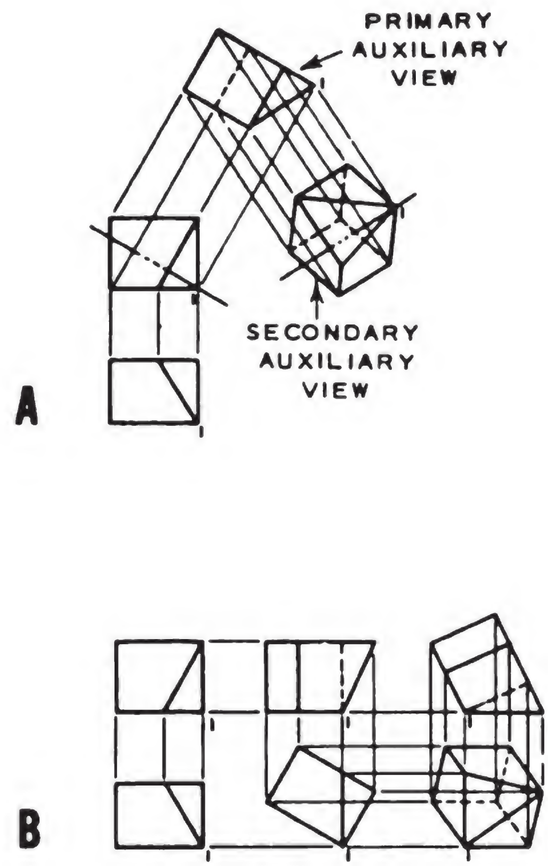

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Figure 3–19.—A. Double auxiliary. B. Successive revolution.

In figure 3–19B, the object is first revolved about a horizontal axis. Next the revolved top view is again revolved. Lines are then projected downward from it and to the right from the revolved front view to find the points on the side view. This view then shows the oblique surface of the object in its true shape and dimensions.

PERSPECTIVE PROJECTION

Perspective drawings constructed by perspective projection are one-view drawings. While they do not show

the object in its true shape and dimensions, they do show how the object looks to an observer and, as a consequence, they are easier to comprehend at a glance than drawings made according to orthographic projection. For this reason, perspective projection is often used for exploded views of objects to show all the different parts and their relationship to each other. Perspective projection is also sometimes used for architectural renderings of proposed structures to show how the structures will look when they are completed.

Perspective projection drawings requiring very accurate projection are usually done by working from orthographic views of the object. For purposes of illustration, however, this type of painstaking projection is not necessary. Many illustrators do not use the methods of perspective projection at all, making their perspective drawings by approximating the positions of various planes. But, unless you are a very keen observer and have had considerable practice, you are likely to commit some rather ridiculous errors if you try to draw perspective illustrations by guesswork alone. A few simple rules and a few pains taken in constructing a scene or an object will help you make better drawings.

One-Point Perspective

Figure 3–20 is a one-point perspective projection of a cube from a top and side view in orthographic projection. The technical terms which will be used in discussing perspective projection are illustrated in the figure.

Notice that the PICTURE PLANE becomes a line in the top and side orthographic views. Projectors from the corners of the top view are drawn converging toward the STATION POINT but, from the points where the projectors, or visual rays, pierce the picture plane, parallel projectors are drawn down to the perspective view.

The station point for the side view is actually the same station point as that shown for the top view. It is,

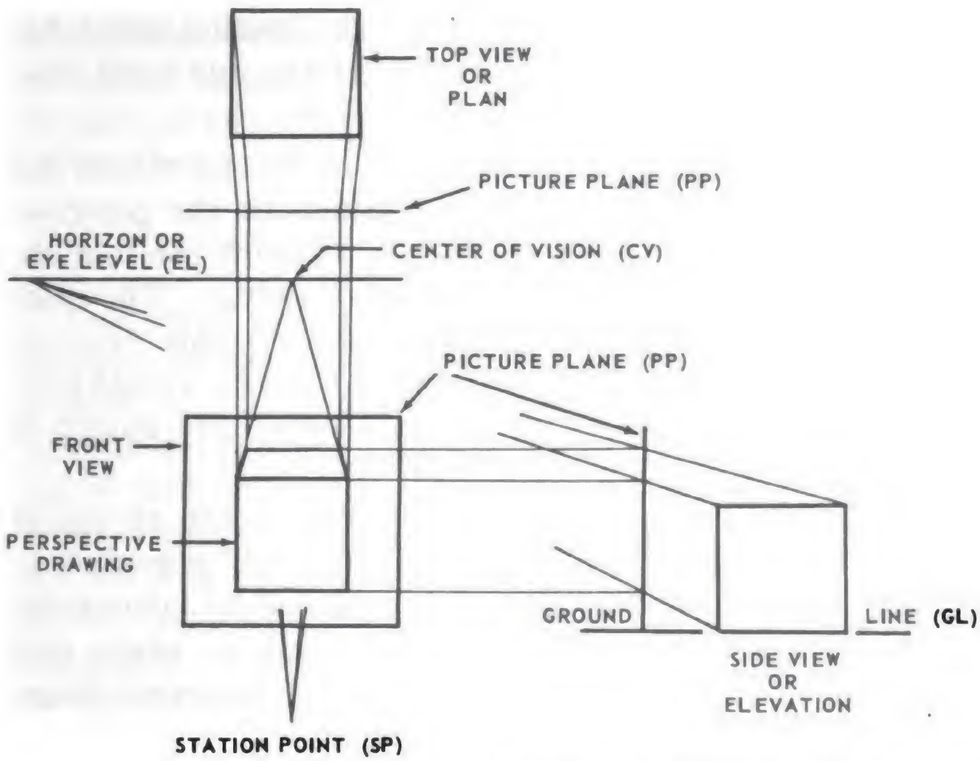

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Figure 3–20.—One-point perspective drawing obtained from orthographic views.

therefore, the SAME HORIZONTAL DISTANCE from the cube, but its elevation shows the height of the station point above the level of the cube. The picture plane in the side view is also the SAME DISTANCE from the cube as in the top view, and the ground line in this view, on which the picture plane rests, DEFINES the ground line of the picture plane in the perspective drawing.

In the side view, projectors are drawn converging to the station point, and at their piercing points on the picture plane, parallel horizontal projectors are drawn to the perspective drawing. The intersection point of a projector from a corner of the cube in the top view with the projector from the same corner in the side view locates the corner in the perspective drawing.

Notice that the center of vision in this drawing is located directly above the station point in the perspective

drawing and on the same line with the station point for the side view of the cube. This line is the eye level line. It is also the horizon line for the drawing.

The center of vision defines the point at which all lines perpendicular to the picture plane in the perspective drawing converge. It also coincides with the vanishing point in one-point perspective drawings. The fact that there is only one vanishing point in this type of perspective drawing gives it its name. It is also called parallel perspective because the front face of the object is parallel to the picture plane.

In parallel perspective drawings, the center of vision is not necessarily centered on the object. It may fall to one side or the other as shown in figure 3–21. However, when the front face is parallel to the picture plane and the center of vision is at one side of the drawing, there will necessarily be some distortion. Actually, the drawing becomes an oblique projection and not a true perspective drawing. Notice that in order to make such a drawing, the object must be considered as resting with its front face against the picture plane. If this were not so, converging projection lines from the corners of the

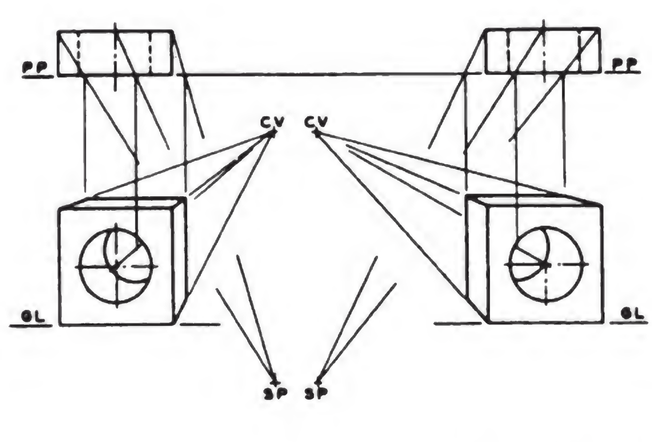

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Figure 3–21.—Position of the station point at right or left of center in parallel perspective drawings.

front face would alter its appearance so that it would no longer appear to be parallel with the picture plane. In fact, as you will see, it would then become a two-point, rather than a one-point, perspective drawing.

Two-Point Perspective

Two-point perspective is the most commonly used method for making perspective drawings. In two-point, or angular perspective, the object is considered as sitting at an angle to the picture plane. In the perspective drawing of such an object, there are 2 sets of horizontal edges converging toward 2 different vanishing points on the eye level or horizon line. The parallel lines which slope to the right will vanish at a point in the distance called the right vanishing point (*VPR*) and those that slope to the left at a point called the left vanishing point (*VPL*). (See fig. 3–22.)

In the figure, the top orthographic view of the block was drawn first. The position of the picture plane was then determined.

When the corner of the object rests against the picture plane, the vertical line representing the corner in the perspective drawing will be full size. In one-view perspective, the front face is full size in the perspective drawing if it rests against the picture plane. In any perspective drawing, the comparative sizes will be reduced proportionately as the distance is increased between the picture plane and the object.

Once the picture plane was established, the station point for the top view in figure 3–22 was located approximately opposite the center of the block. The distance from the station point to the object should not be less than twice the width of the object.

When this rule is neglected, a distorted appearance may result in the perspective drawing. There is a cone of about 30° in which the human eye sees clearly. For this reason, the angle formed by the lines of sight from the sides of the object to the station point should not

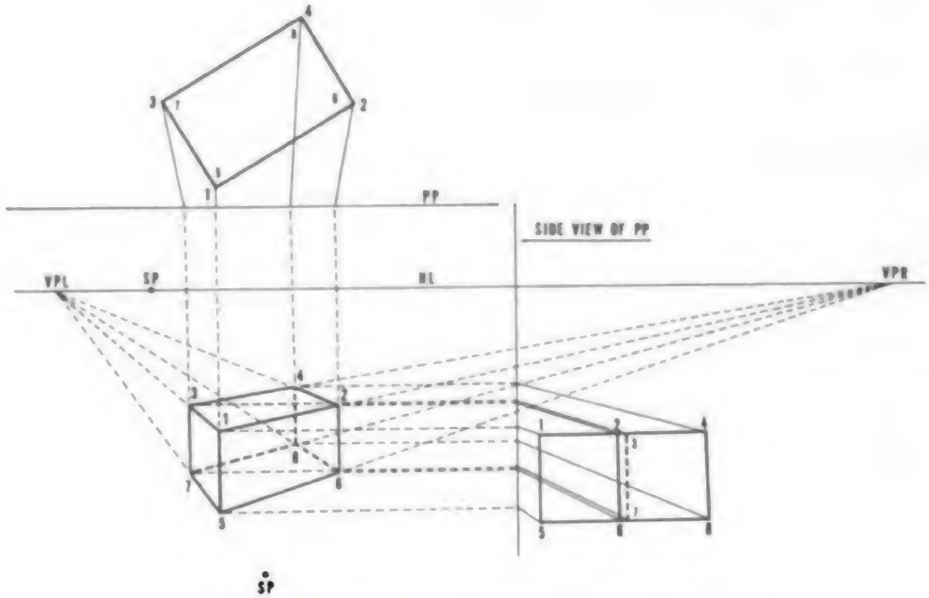

Figure 3–22.—Two-point or angular perspective.

exceed 30°. In no case, even when the perspective drawing depicts a panoramic scene, should it exceed 45°.

Next, the picture plane for the side view was established. Then the side view was drawn. (Points may be projected from the top view if necessary.) Remember that the picture plane in the side view or elevation is the same picture plane shown in the top view and, thus, it is the same horizontal distance from the object.

The station point for the side view was located next. This station point is the same point seen in the top view and, therefore, it is the same horizontal distance from the object. However, its angle to the object can vary. This variation of the station point in the side view determines the height of the eye level or horizon line. Note that the station point for the side view always falls on the horizon line.

This horizon line is a very important one. If it is high, objects in the perspective view will appear as if they were viewed from a height. If it is low, objects

will appear as if they were viewed from directly in front or below. (See fig. 3–25.) Generally, it is best to select a station point approximating that from which a real observer might view the object.

This method is usually used when architectural drawings are made in two-point perspective. However, two-point perspective may be drawn from the plan view of the object alone, without the elevation. When this is done, the vanishing points are first projected on the picture plane and then located on the horizon line. In order to do this, a line parallel to one set of horizontal lines in the top view is drawn from the station point to the line of the picture plane. The point at which this line intersects the picture plane is then projected to the horizon line to locate a new point, either VPL or VPR. (See fig. 3–23.)

When this method is carefully used, it will produce as much accuracy as the method illustrated in figure 3–22. For example, in figure 3–24, the horizon line has been placed at the same level as the horizon line in figure 3–22 and the cube is the same size so that the two methods can be compared. In figure 3–22, the vanishing points were found after the drawing was completed, and it was not necessary that they be found at all. In figure 3–24, the vanishing points were found at the start, because they control the drawing.

In figure 3–24, lines are drawn converging toward the station point from the corners of the block in the top view. From the points where these lines pierce the picture plane, verticals are dropped to give the apparent width of the block in the perspective view. Since an elevation is not used, the various heights cannot be found directly. However, the bottom of the block may be located, as shown in figure 3–24, by drawing lines to the vanishing points from the point selected as the near corner.

Now if the perspective height of any one vertical line can be determined, the height of the other verticals can be found automatically. This is easy to do when one

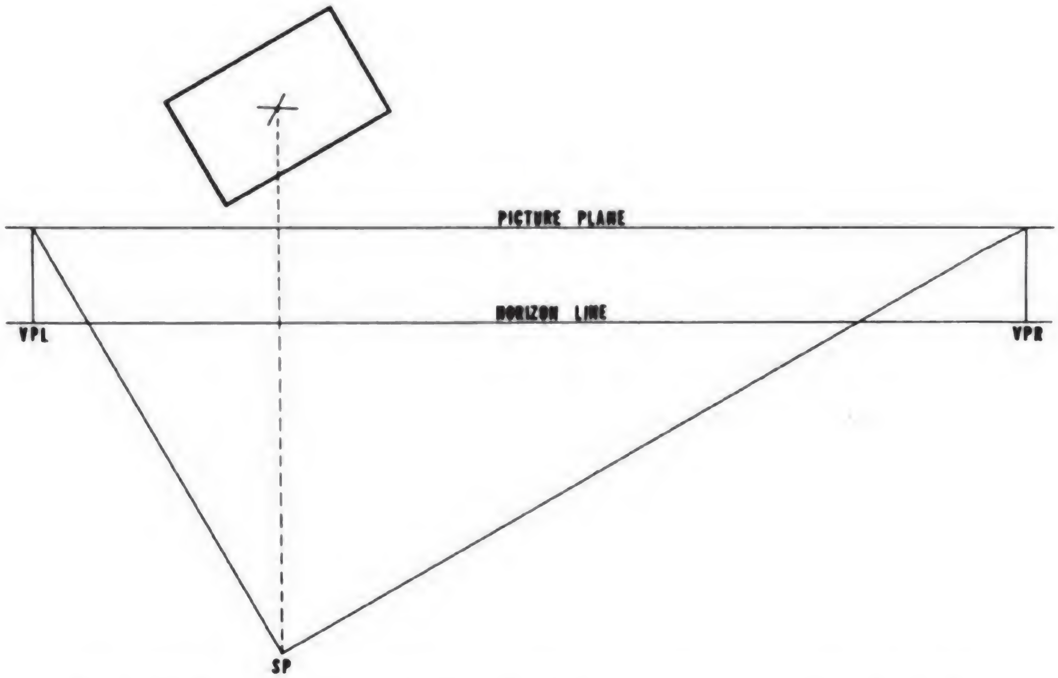

Figure 3–23.—Locating vanishing points for two-point perspective drawn from the plan view.

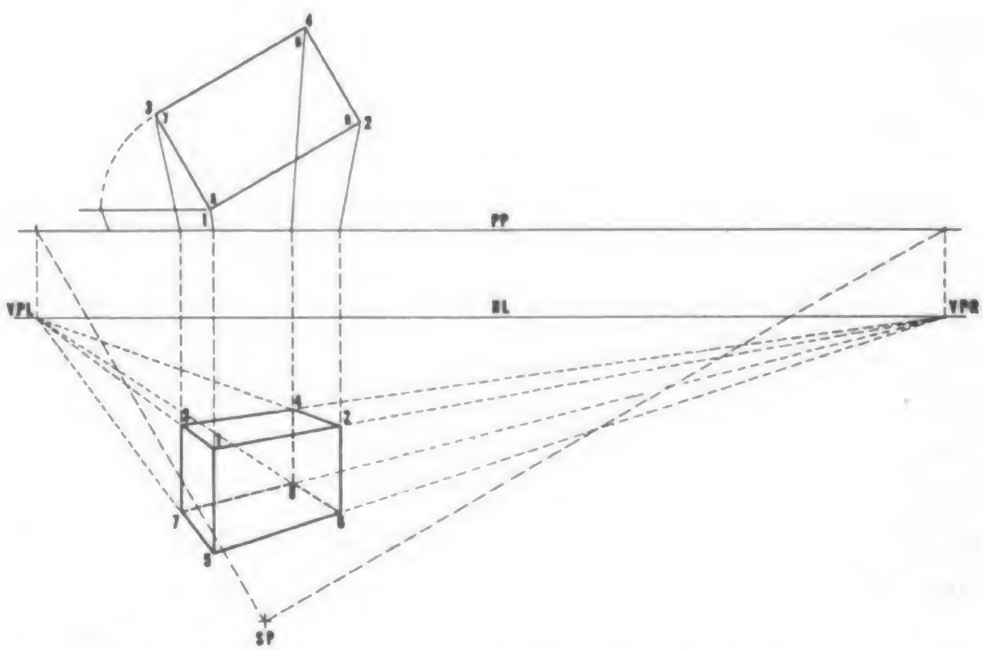

Figure 3–24.—Two-point perspective drawing made without using an elevation of the object.

edge of the object rests against the picture plane. This edge will then appear in its true height in the perspective view. If you have the dimension for this height in the orthographic projection, you can transfer that dimension directly to the perspective view. Lines drawn to the vanishing points from this top corner will locate the top of the two sides, and lines drawn to the vanishing points from the far corners on these sides will complete the drawing of the block.

When the front edge of the subject does not rest against the picture plane, it is necessary to use some other dimension. Since the end of the block is square it is possible to find the perspective length of a horizontal line and use this dimension for the edge of 1–5. This is done, by drawing a line parallel to the picture plane from 1, measuring a length of this line equal to 1–3, and drawing a line converging on the station point to the picture plane from the end of this line.

This length can then be transferred to the front edge of the perspective view and the view completed as shown in figure 3–24. To check the accuracy of this method, compare figure 3–24 with 3–22. You will find that, since the station point, horizon level, and the bottom of the cube correspond, the two perspective views are similar. It is possible to make them correspond exactly.

In figure 3–24 the bottom of the front edge of the block has been placed autocratically at a certain point. Actually it could have been placed on the vertical projection from the cube at any desired point. Thus, the perspective view may be drawn below the eye level, or it may be drawn at eye level or above it, as shown in figure 3–25.

However, if the object is placed too high above the eye level or too low below it, the effect will be one of distortion. A block drawn in these positions will cease to look right, as shown in figure 3–26. When the station point is too close to the object, there will be a similar distortion. The angle indicated in the figure should never be less than 90° and preferably not less than 100°.

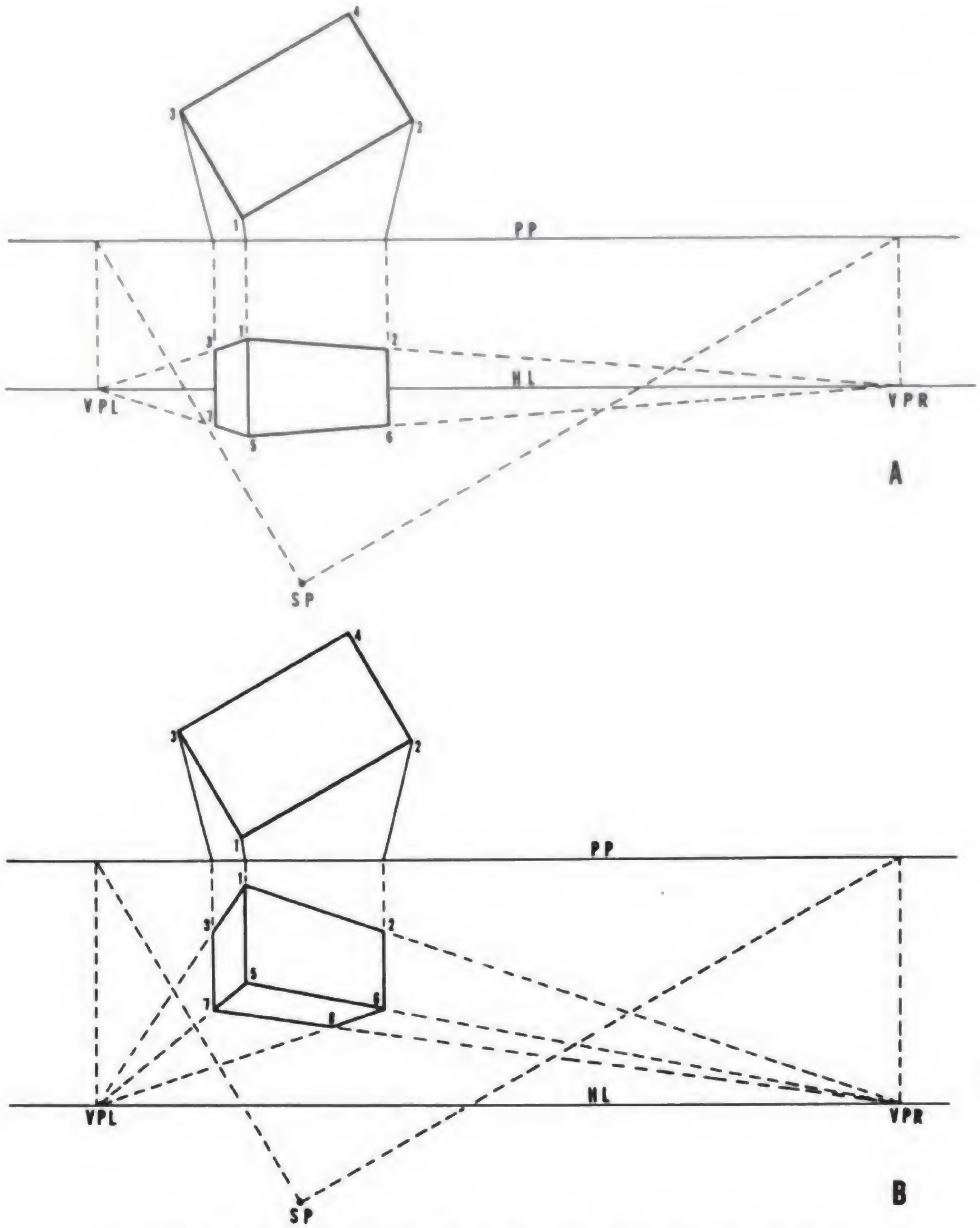

Figure 3-25.—A. Object on eye level. B. Object above eye level.

To overcome distortion such as that illustrated in figure 3-26, the station point may be moved further from the object or the picture plane may be tilted so that a third vanishing point is needed for the third set of parallel lines in the drawing.

Measurements in Two-Point Perspective

In drawing objects with compound shapes, a series

of cubes may be used. If you draw a cube in two-point perspective, you can easily divide the perspective views of the sides of the cube into halves and again into quarters by using diagonals, as shown in figure 3–27A.

The diagonals of the square sides establish the centers of these sides. Verticals erected through each center, divide the sides into halves. In order to divide the squares into quarters, find the center of a vertical side and draw lines from this point receding toward the vanishing points. This establishes the centers of the vertical edges. Now draw a diagonal in one of the quarters so established. This diagonal will cross the diagonal of the large square. Finally erect a vertical through the point estab-

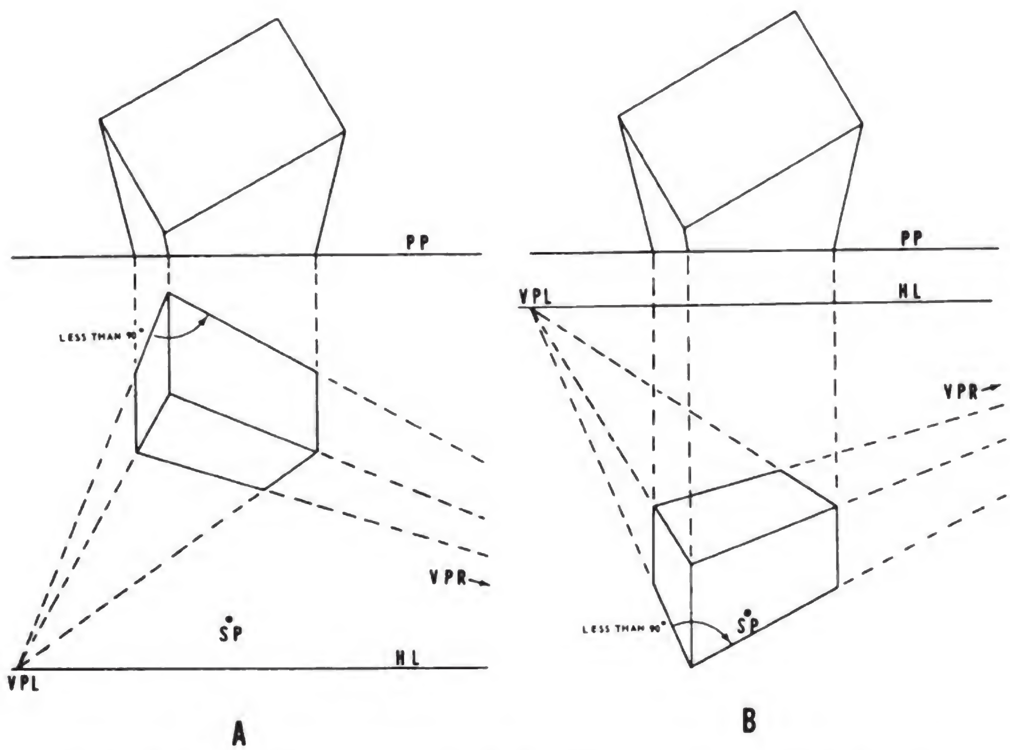

Figure 3–26.—A. Object placed too high above eye level. B. Object placed too low below eye level.

lished by the intersection of these two diagonals. As you can see, this process of division can be carried on as far

as necessary to establish the required division points on a horizontal edge or within the square itself.

It is also possible by using diagonals to add to the sides of the cube in multiples of 2, 4, 8, etc., as shown in figure 3–28. First, the center of the square side is found and a vertical and horizontal are drawn through this center. The horizontal is extended beyond the side of the cube toward the vanishing point and the horizontal edges of the side are also extended toward this point, as shown in figure 3–28A.

A diagonal drawn from the center point on the lower horizontal edge of the square through the center point on the far edge will intersect the extension of the top edge as shown in figure 3–28B. A vertical dropped from

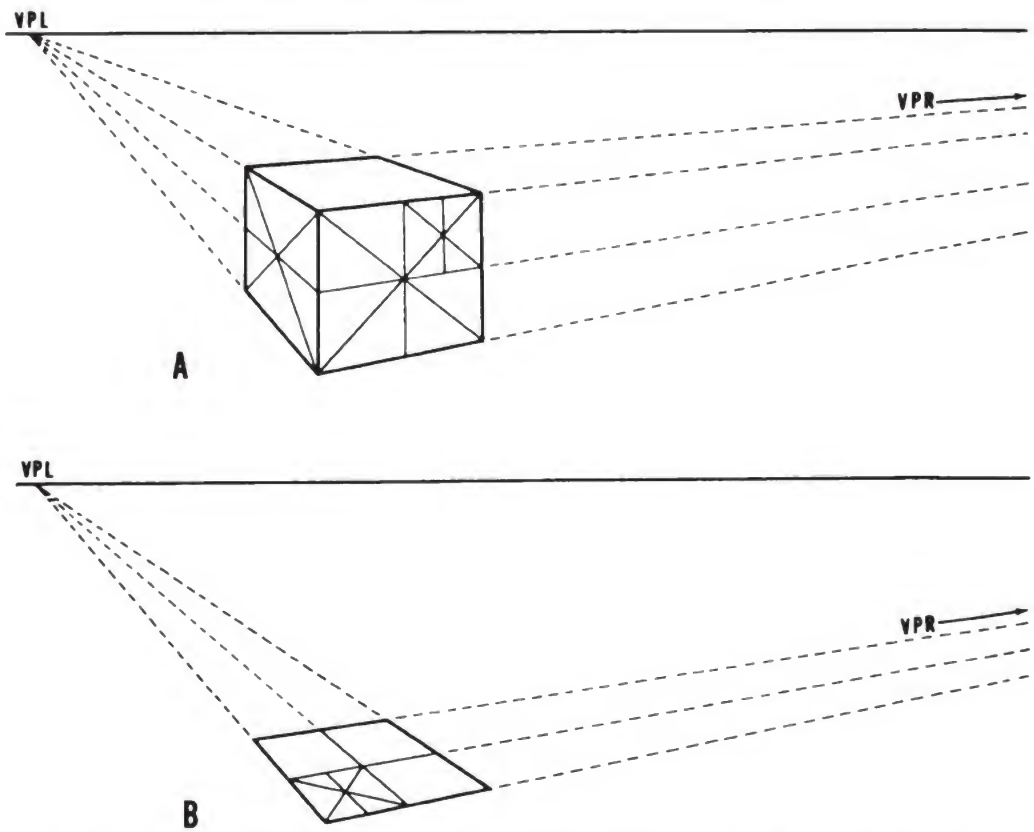

Figure 3–27.—Using diagonals to establish divisions on a line or a plane in perspective.

this intersection will add the equivalent of a half to that side. As you can see, this process can be continued as many times as necessary, and the sections so established can be divided in turn.

Now suppose you are asked to draw in perspective a bookcase 36 inches high, 24 inches wide, and 12 inches

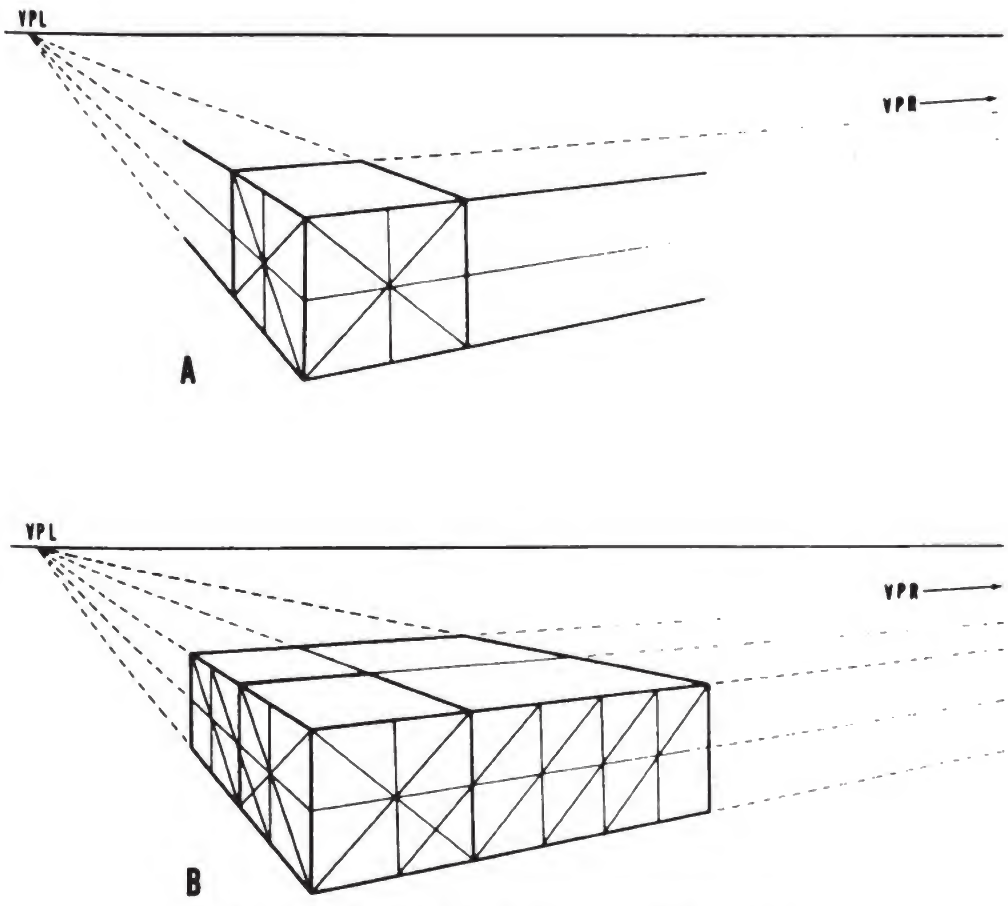

Figure 3–28.—Using diagonals to multiply areas.

deep. Since the 36 inches can be divided into 18 inches or 9 inches but not into 24 or 12, it will be better to make the basic cube 24 inches, which can easily be divided into 12 inches and to which 12 inches can be added. In figure 3–29B, these dimensions have been

established. Note that the same method used for multiplying areas in a horizontal direction, shown in figure 3–28, may be applied to multiplying them in a vertical direction.

Suppose that the bookcase is constructed of boards which are 1 inch thick. The top shelf is 8 inches high—that is, the upper front edge is 9 inches from the top of the bookcase, and the lower shelves are 12 inches high—that is, 13 inches including the width of one shelf—with the lowest shelf resting on the floor. Notice that 9 inches is one-fourth of the total height of the bookcase, which should make it easy to find this dimension. A diagonal may be used to create a 36-inch square, as shown in figure 3–30A, and diagonals may be used to locate the top shelf, as shown in figure 3–30B.

If either of the verticals bounding this shelf can be easily divided into nine of some convenient unit, such as an eighth of an inch, the width of the board can be found for that vertical, as shown in figure 3–30C. Since the bottom of the front edge of the second shelf is one-half the remaining distance, this dimension may be located by using dividers. The width for the horizontal shelf boards may be easily estimated. (See fig. 3–30D.)

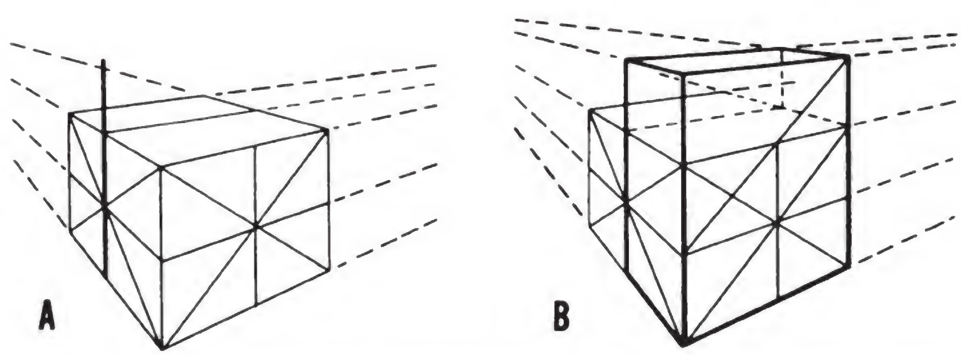

Figure 3–29.—Finding the outside dimensions of a bookcase in perspective.

Next work out the rear edge of each shelf, starting

by finding the front edge of the backboard. This will be one inch from the rear edge of the bookcase itself. The measurement may be approximated. Mark a point one inch from the back of the bookcase on each of the lines. From these points, draw lines toward the right vanishing point to define the rear edges.

To define the inside edges of the shelves at the right side of the bookcase, draw lines toward the left vanishing point from the points where the top edges of the front of the shelves meet the right side of the bookcase. Where these two sets of lines intersect, erect a vertical.

When the problem consists of finding equal division points of a plane in perspective, such as a line of telephone poles along a road or equally spaced divisions on a wall or a floor, and the spacing of these points is known, the problem may be solved as shown in figure 3–32. Since the points are parallel on the object, they will have a common vanishing point. If the plan view is used, the points may be projected to the picture plane in that view as shown in figure 3–32A. Then they are

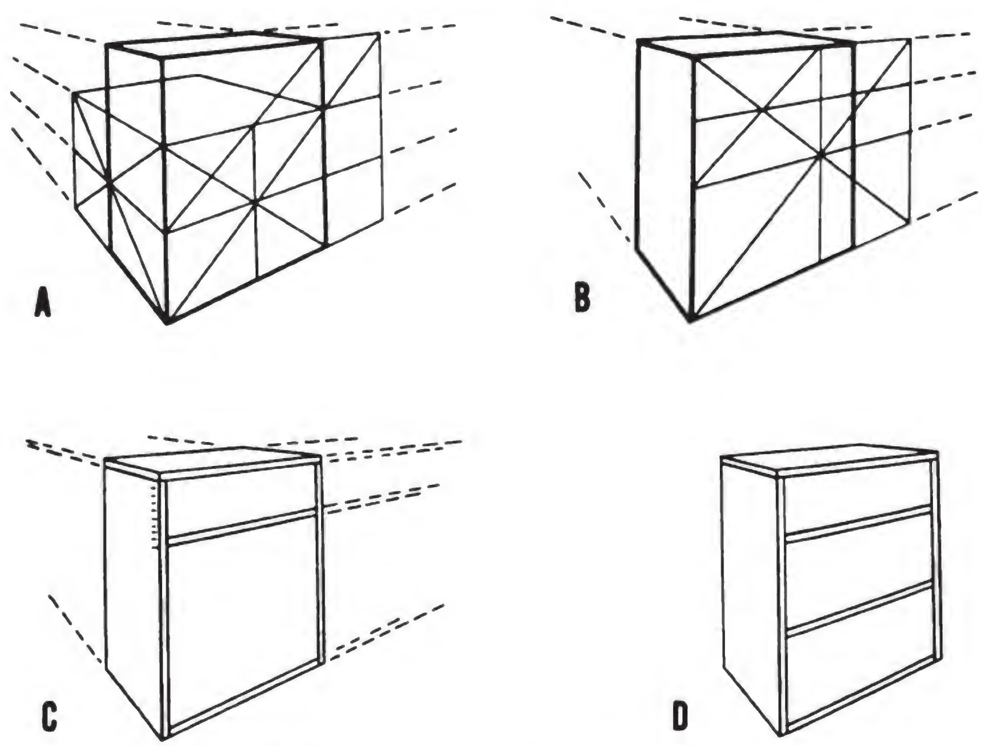

Figure 3–30.—Locating the shelves of the bookcase.

projected to the picture plane in the perspective view, and lines are drawn toward the vanishing point.

If no plan view is used, a horizontal line is simply drawn, as shown in figure 3–32B, and the points spaced off on this line. Notice that this method of finding the position of equally spaced points on a line is very much like the common method of dividing a line into equal spaces.

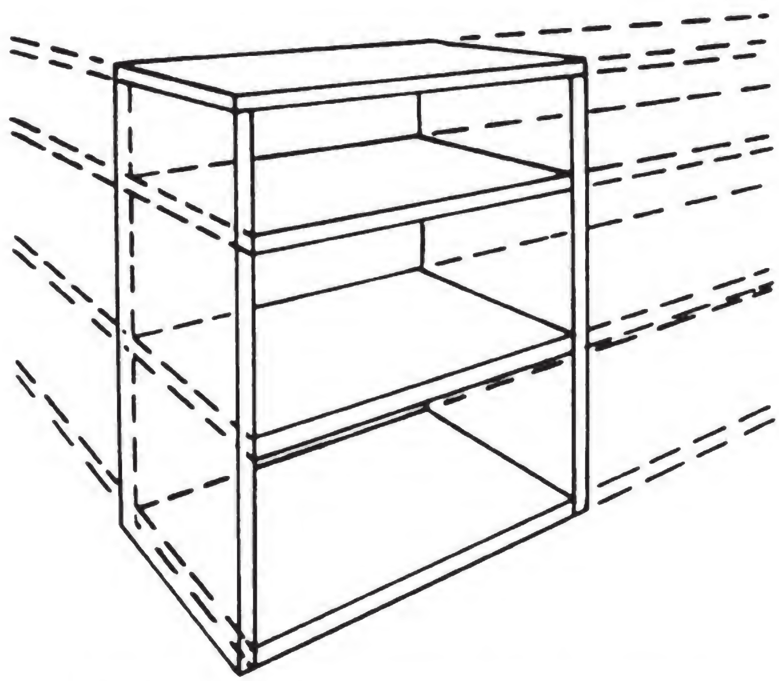

Figure 3–31.—Locating the rear edges of the shelves.

Vanishing Points for Inclined Lines

Just as horizontal planes vanish at the horizon line and horizontal lines vanish at a point on the horizon line, so inclined planes will vanish on a line and inclined lines which are parallel on the object will vanish at a point on this line. The vanishing line for inclined planes will always be a vertical passing through one of the two

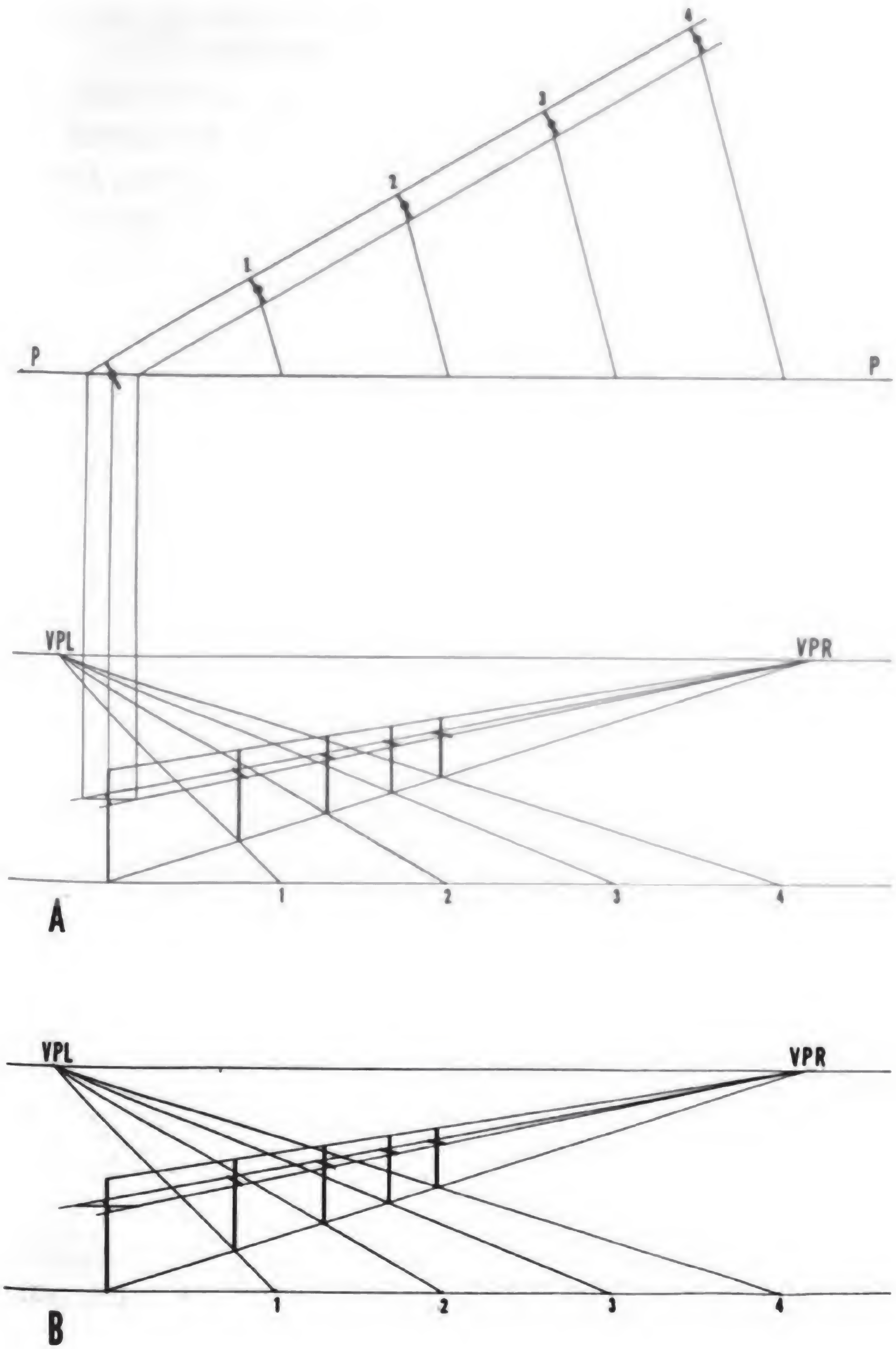

Figure 3–32.—Measurement of horizontal points that are equally spaced.

vanishing points, while the vanishing point for parallel inclined lines will fall somewhere on this line.

In figure 3–33, the vanishing points of 3 pairs of parallel lines defining 3 inclined planes are found on the vertical line erected for *VPR*. In the drawing, a plan view of the object was used and the station point was located. Then the vanishing points were found by the method shown in figure 3–23.

Points on horizontal and vertical planes can then be found by methods previously described. That is, lines are drawn converging on the station point from these points in the plan view to the picture plane and from the picture plane they are projected to the perspective view. Since the front edge of the plan view rests against the picture plane, the length of this edge is the same as it is in the orthographic drawing and can be projected directly from the elevation at right. From this edge, lines can be drawn converging on the left and right vanishing points.

However, the points on the inclined planes are not so easily found. In order to locate point *A*, it can be assumed to be moved forward to the picture plane, as shown by faint crosses; and measuring lines drawn down from the picture plane. The true height can then be projected from the elevation to intersect these lines. Lines are drawn from these points to the vanishing points. Point *A* is then established for the perspective drawing as the point where these receding lines cross. The other points in question can be found in the same way.

A line drawn from A^1 through *A* in the perspective drawing to the vertical passing through the right vanishing point establishes the vanishing point for all other inclined lines parallel with this one.

The vanishing point of the edges of inclined planes is found in the same way since the lines defining them are parallel lines on the object.

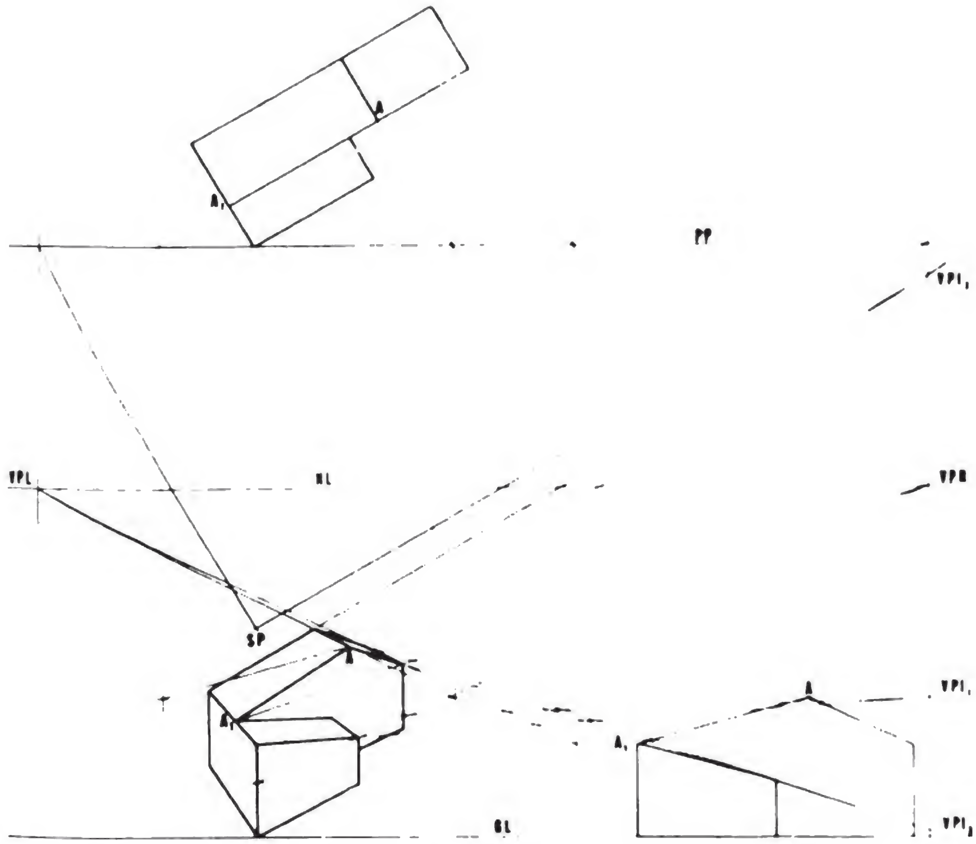

Figure 3–33.—Finding the vanishing point of inclined lines.

Measuring Lines

Measuring lines are often used in architectural drawings to locate points which do not fall in the picture plane. In the drawing in figure 3–34, the station point, ground line, and picture plane were located first. The eye level, or horizon, line was drawn about 5 feet 6 inches on the selected scale above the ground line, and the vanishing points were located on it.

Next the plan and elevation were drawn to the same scale. In the plan view, the peak of the roof was moved forward to contact the picture plane and then a measuring line dropped vertically from this point. From the elevation, the true height of the peak was projected to this measuring line and a receding line drawn from

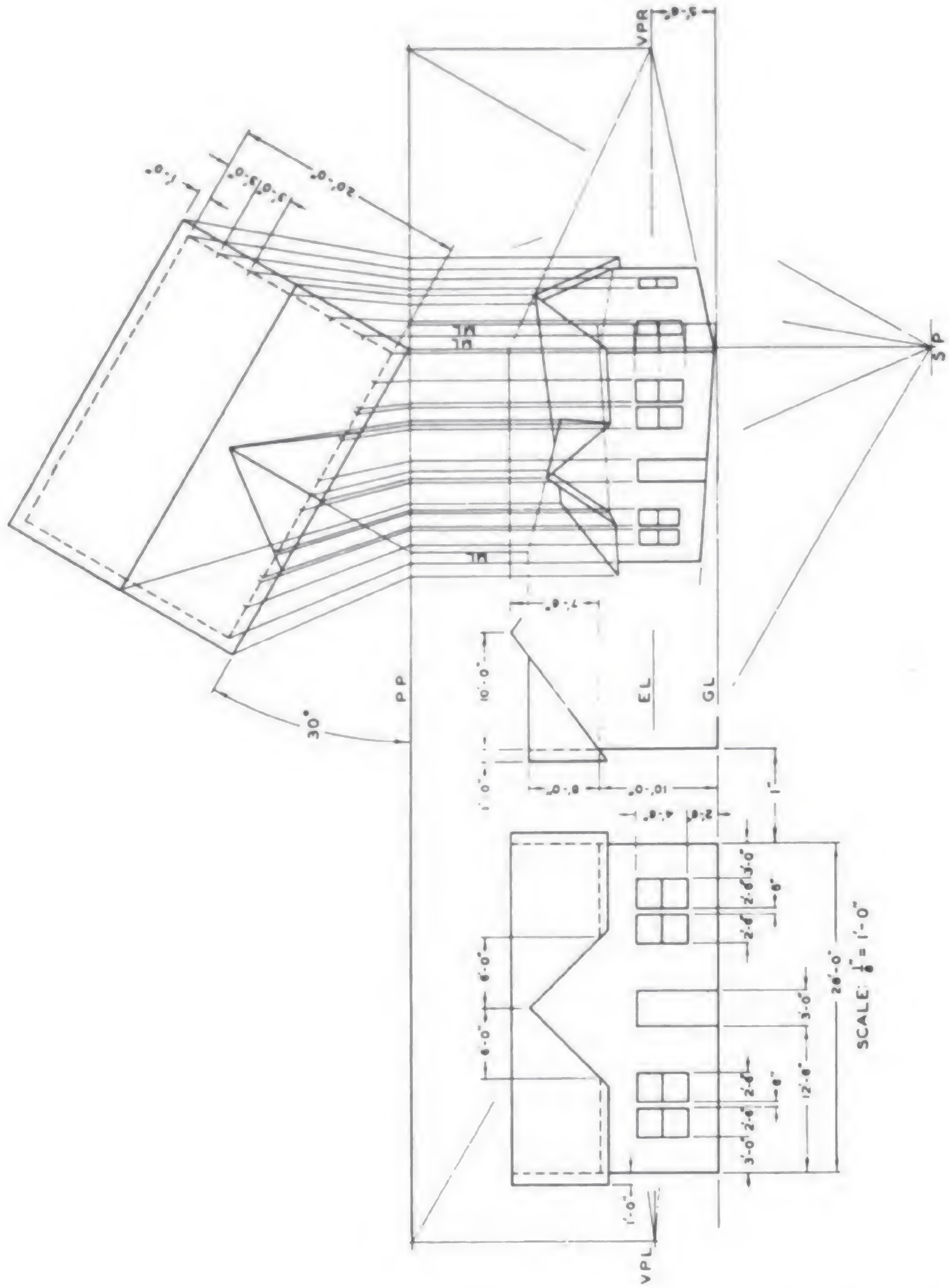

Figure 3–34.—Measuring lines in two-point perspective drawings.

this point in the perspective drawing to the right vanishing point. Then the outlines of the roof were drawn. The peak of the dormer was located in the same manner and the dormer drawn. Next the right edge of the cottage was moved forward to the picture plane and a measuring line drawn from this point to intersect the line from the elevation. The true heights of the wall, door, and windows were marked on this line, and the receding lines from these marks to the vanishing points drawn to locate these features in the perspective drawing.

Curves

Just as the square and the cube are the basic shapes for constructing figures with straight lines, the circle and the sphere are the basic shapes used in constructing most curved forms. The circle seen in perspective appears as an ellipse, but it may be placed and sized most easily if it is constructed within a square.

In figure 3–35A, a circle has been placed in a square. In figure 3–35B, the same square is constructed in parallel, or one-point, perspective, and the circle is placed in it. In this case the minor axis coincides with the receding centerline of the square, but the major axis does not coincide with the centerline in the other direction.

A discussion of methods for drawing the ellipses formed by circles on receding planes in oblique and isometric drawings is included in *Draftsman 2,* NavPers 10473. The four-center method is one of the simplest and most commonly used. Remember that when the ellipse represents a wheel, the major axis is perpendicular to the axle. When it is necessary to draw an ellipse with great exactness, the methods discussed in *Draftsman 3,* NavPers 10471, may be used.

It is always possible to transfer a curve from an orthographic view to a perspective view by locating

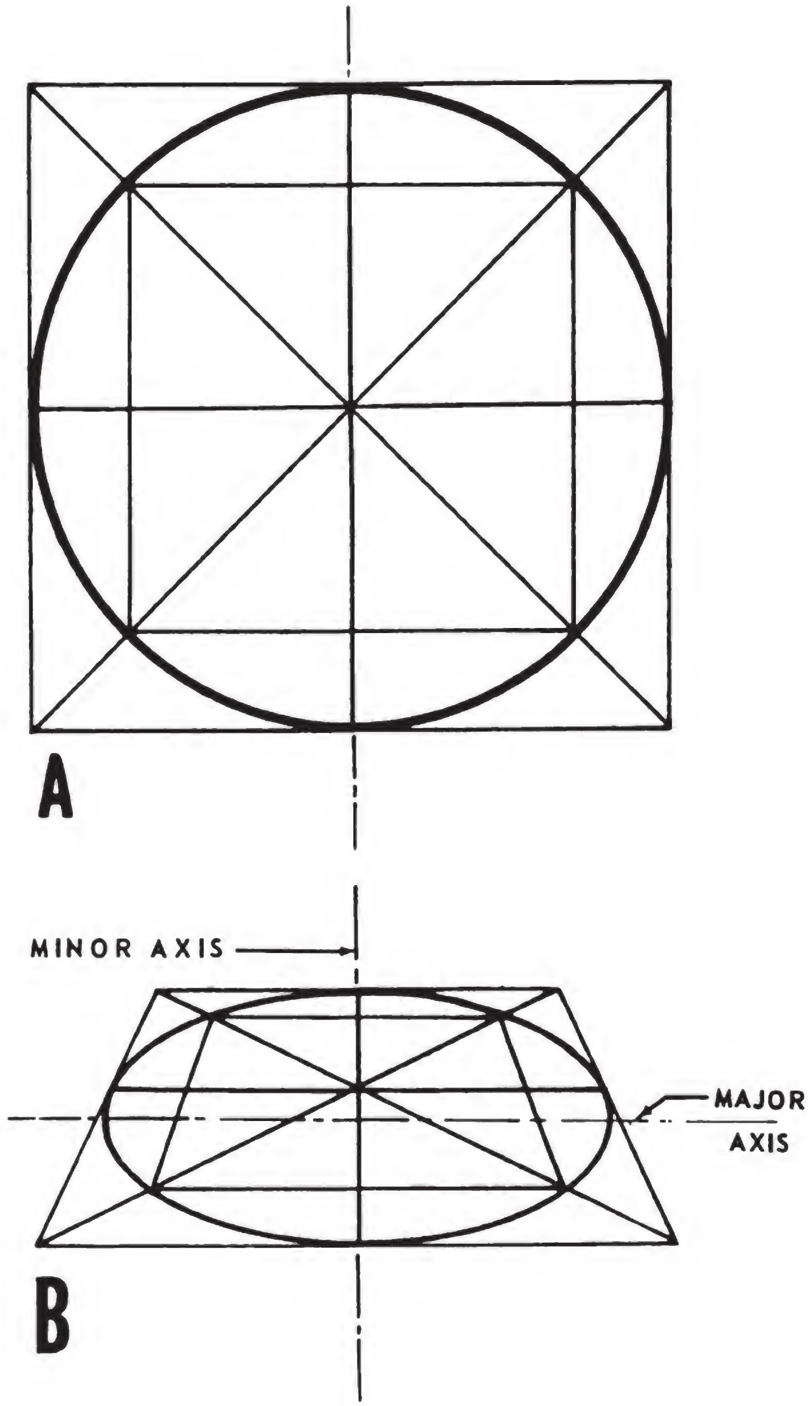

Figure 3–35.—A. Circle in a square. B. Same circle and square drawn in perspective.

points on the curve in the orthographic view and projecting these points to the perspective view. This method is illustrated in figure 3–36.

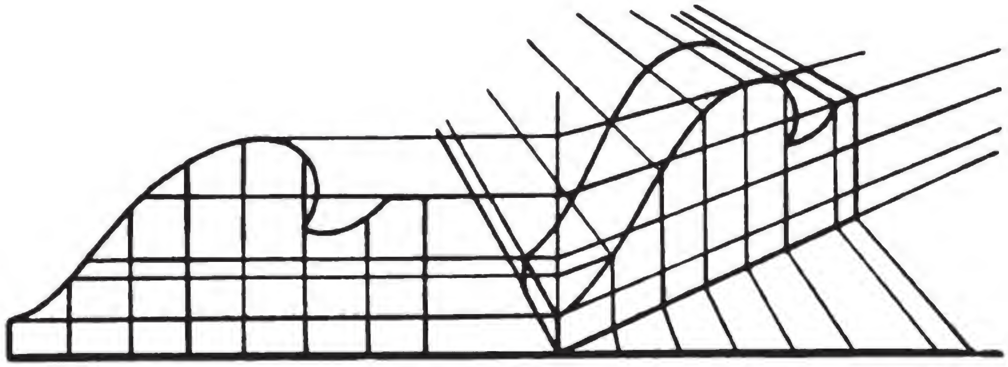

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Figure 3–36.—Drawing a curve in perspective by transferring points from an orthographic view.

Figures in Perspective

One thing that will spotlight a poor illustration is the failure to draw figures in perspective. No doubt you have seen an illustration which made you vaguely uncomfortable although at first glance it seemed well drawn. A second glance may have revealed that one of the main figures was standing on thin air, or, if not, he was a giant. This sort of thing is easy to avoid if you work out the perspective.

In a simple case, where a group of people are standing on a flat plane with the eye level at normal height, the position of each individual can be determined by drawing the verticals from the plane to the eye-level line and then drawing each in proportion on this line. (See fig. 3–37.)

When the station point is above or below the group, the placement of the figure is not so simple. If a vertical

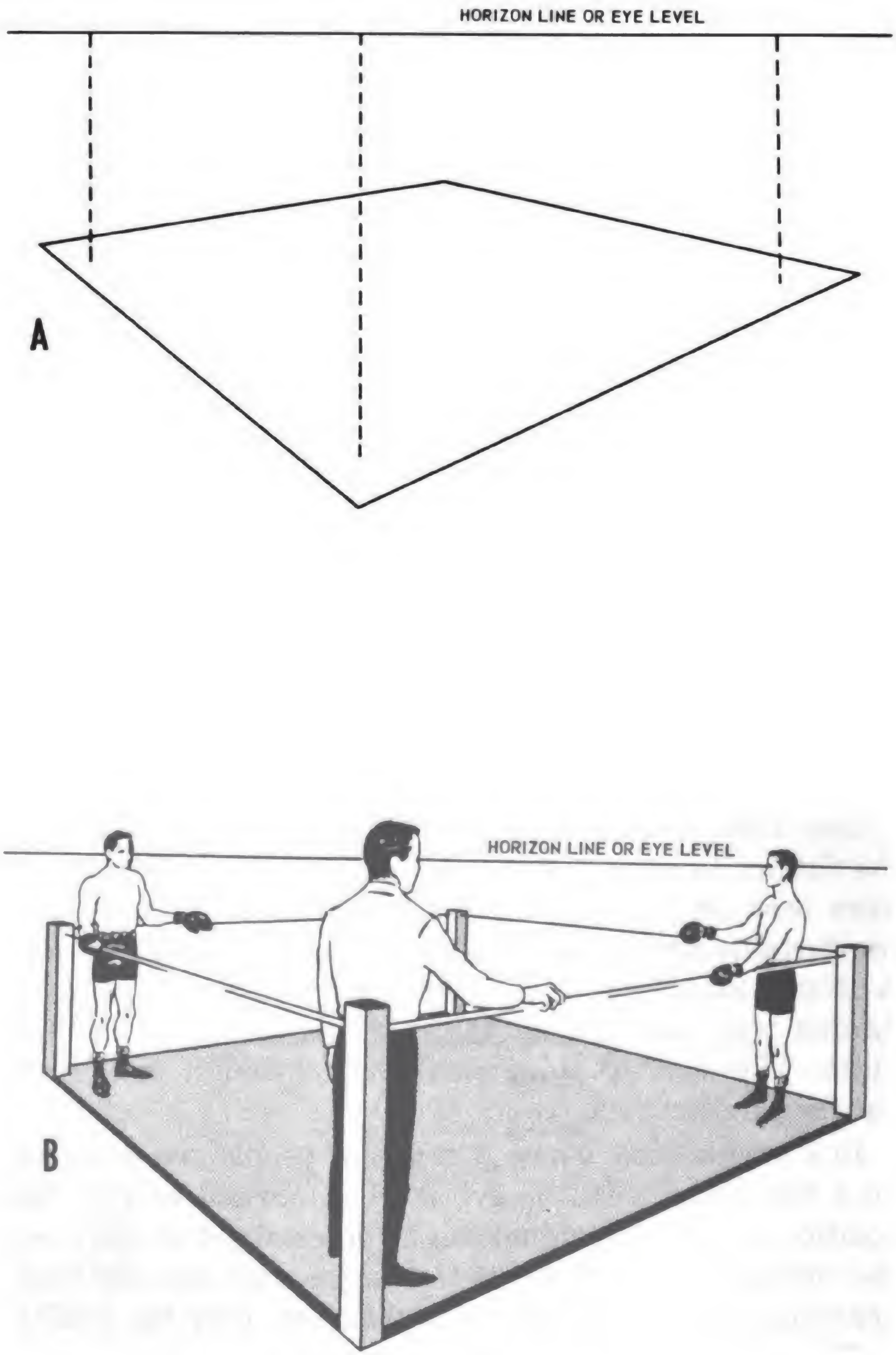

Figure 3–37.—Group of figures in perspective.

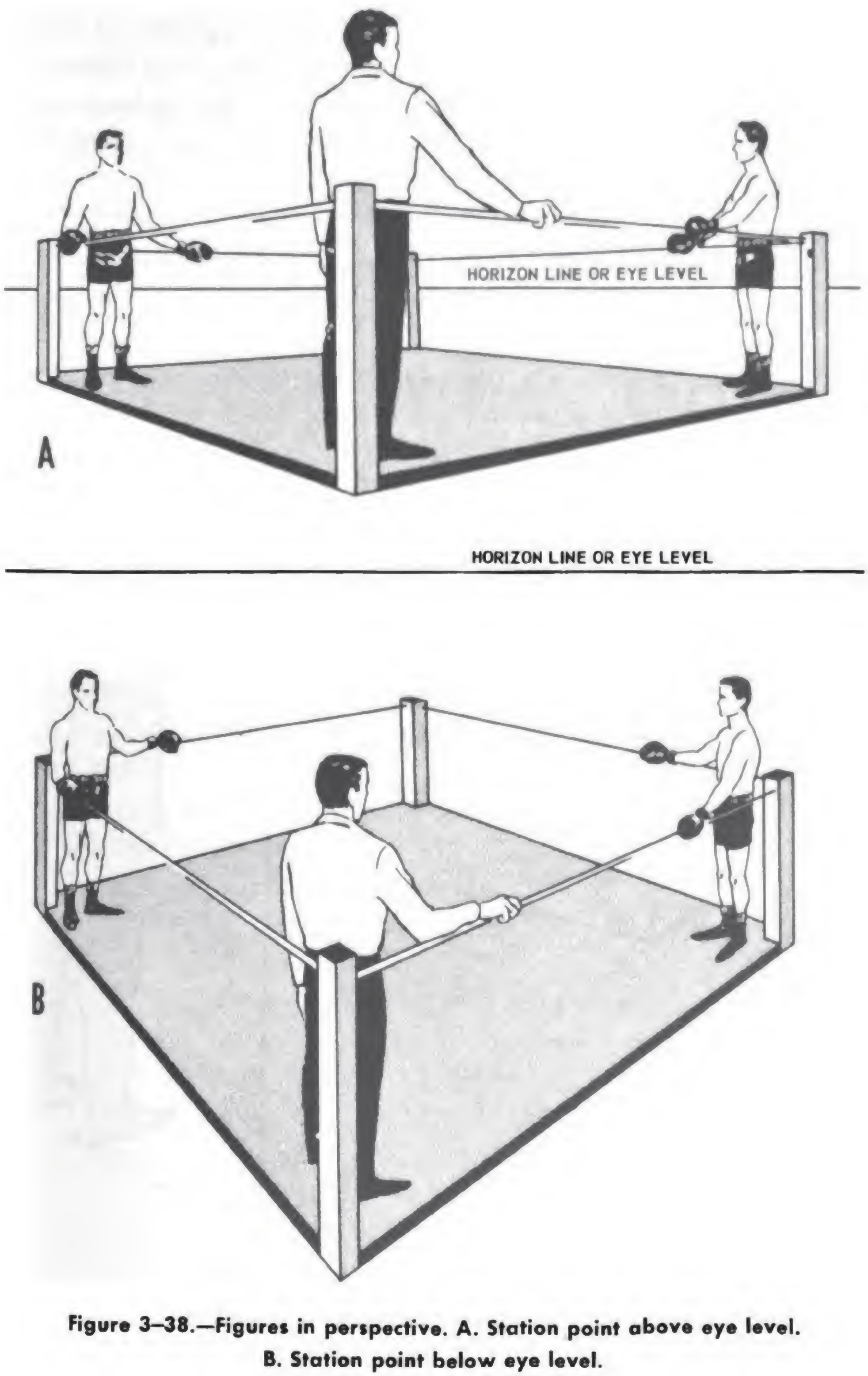

Figure 3–38.—Figures in perspective. A. Station point above eye level. B. Station point below eye level.

line can be established at the correct height, a reference plane may be drawn in perspective and the various figures placed and sized in relation to this plane. (See fig. 3–38.)

It is somewhat more difficult to draw figures at different levels, but if you use reference planes, as shown in figure 3–39, such problems may also be solved quite simply. The point is that if you work out your perspective first, you will avoid trouble later.

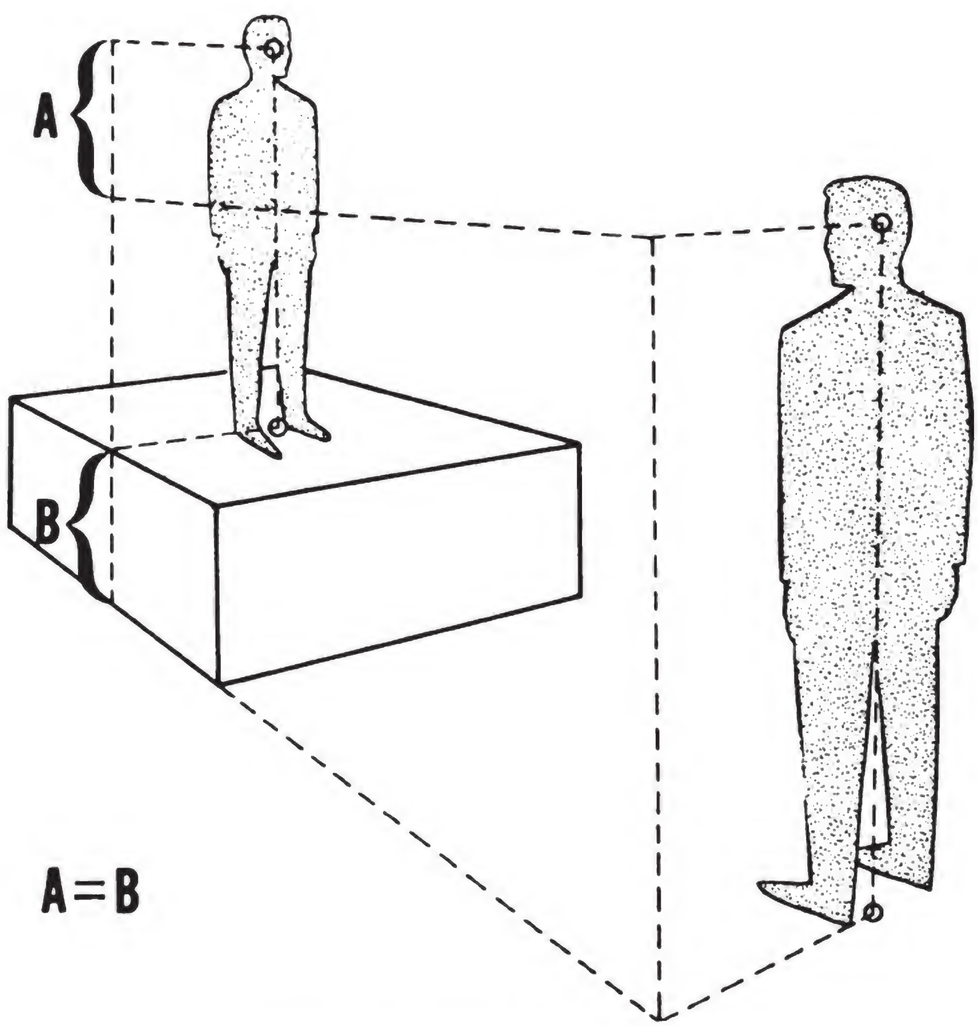

Figure 3–39.—Figures at different levels.

QUIZ

1. What are the two projection methods in use in engineering drafting?
2. How does parallel projection differ from perspective projection?
3. Into what two classifications can parallel projection be divided?
4. When is an auxiliary view used in third-angle orthographic projection?
5. (a) To what plane is a primary auxiliary view hinged?
   (b) What is its relation to the other two views?
6. What is the chief purpose of an auxiliary view?
7. Why is only the inclined portion of an object generally shown in the auxiliary view?
8. What other purpose besides showing the shape of an inclined portion of an object do auxiliary views sometimes serve?
9. When is a reference plane used in a drawing of an auxiliary view?
10. When is it necessary to draw a secondary auxiliary view?
11. How is the method of revolution used to obtain the same results as auxiliary views?
12. Why is perspective projection often used for exploded views of objects?
13. How many vanishing points are used in one-point perspective drawings?
14. When is a line or a plane drawn full size in a perspective projection drawing?

CHAPTER 4

MECHANICS, STATICS, AND STRENGTH OF MATERIALS

INTRODUCTION

Mechanics is the oldest and simplest branch of physics. It deals with the motion of bodies and the equilibrium of forces. Before you read this chapter, it is suggested that you read the training course *Basic Machines*, NavPers 10624. This course gives a description of the simple machines—the lever, block and tackle, wheel and axle, inclined plane and wedge, and the screw. The concepts of work, power, force, energy, and pressure are also discussed in it.

FORCE is an action upon a body which tends to set it in motion or to change its state of motion. Where there is an equilibrium of forces, no change occurs, but each force must be balanced by one or more other forces acting in the opposite direction.

WORK is done when a resistance is overcome by a force acting through a measurable distance. Therefore, in mechanics, work is a measurable quantity based on resistance (a measurable quantity), force (a measurable quantity), and distance (a measurable quantity). The measurement of quantities is basic to all physics.

VECTORS

All quantities can be classified in one of two groups—SCALAR QUANTITIES or VECTOR QUANTITIES. A scalar quantity can be specified by magnitude alone, for example, quantities of money, wheat, books, etc.

There are certain types of quantities which we must deal with in physics and mathematics which cannot be completely specified by magnitude alone, but which involve also the idea of direction. These quantities are called vector quantities. Examples are displacement, velocity, acceleration, and force. They can be represented and analyzed graphically by means of lines of appropriate length and direction, called VECTORS.

For example, a force can be represented by a straight line. One end of the line represents the point at which the force is applied. The direction of the line, indicated by the arrowhead, represents the direction in which the force is applied. The number of units in the length of the line represents the number of units of force.

Suppose that two forces are acting on a particle from different directions, and you wish to know the total effective force being exerted on the particle. This force which represents the total of two or more forces is called the RESULTANT. You can find this resultant by drawing a diagram representing the two forces acting on the particle as shown in figure 4–1A. Then complete

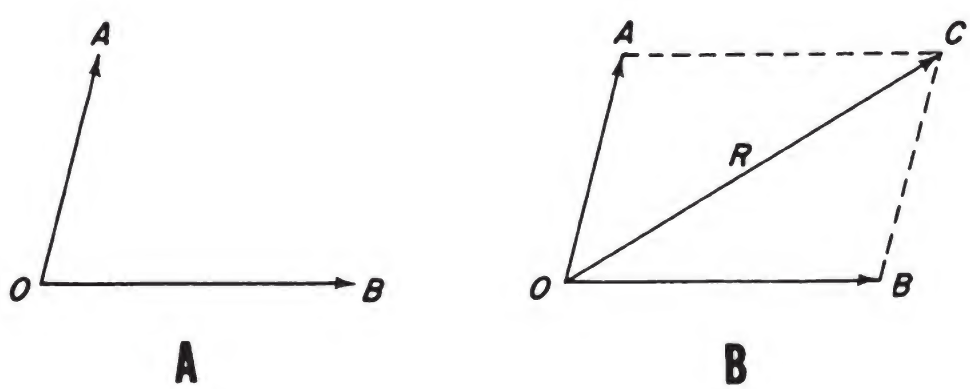

Figure 4–1.—Parallelogram of forces.

the diagram by drawing dotted lines parallel to the lines of the forces to form a parallelogram. The diagonal of this parallelogram is the resultant of the two forces, as shown in figure 4–1B. That is, force *OA* and force *OB* cause the same result on the particle as force *OC*.

In figure 4–1, the spatial relationship of the forces in relation to their point of application is maintained. The same resultant can be found by constructing a triangle, as shown in figure 4–2. You can start with either of the forces and add the second at its end, being careful to preserve the length and direction, as shown in figure 4–2A. Now, the third side of the triangle is the resultant. Notice, that it is the same length as the diagonal in figure 4–1.

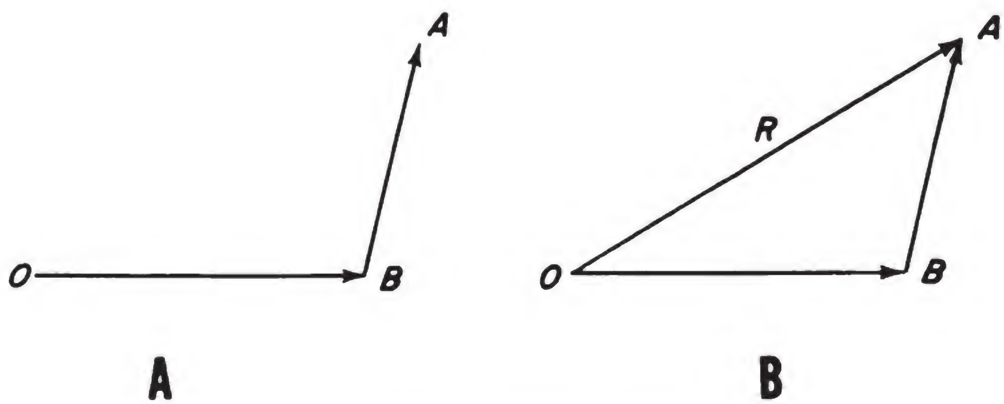

Figure 4–2.—Triangle of forces.

This is the same as adding distances and directions. For example, if a man walks 3 miles east and then turns and walks 4 miles north, and you wish to find the distance in a straight line between the point where he started and the point that he finally reached, you can add the displacements by drawing a triangle as shown in figure 4–3. You can find the length of the third side by measuring it directly, or by mathematics if greater accuracy is desired.

In adding vectors graphically, the added quantities are placed tail to head. The sense of the resultant will be from the tail of the first vector toward the head of the last vector.

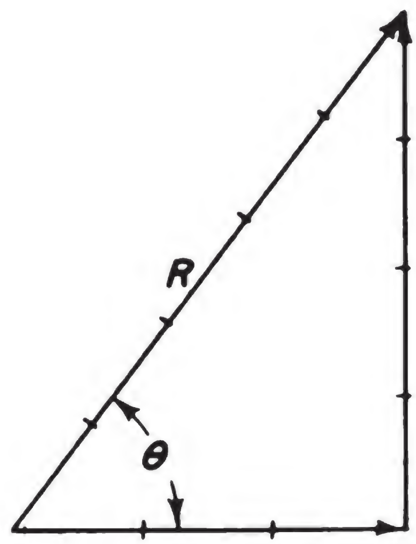

Figure 4–3.—Adding directions of quantities.

Just as it is possible to find the resultant vector when the component vectors are known, it is likewise possible to break down a known resultant into any number of desired COMPONENTS. In figure 4–4A, the resultant and the lines of action of the two components are given. When the parallelogram is completed with lines parallel

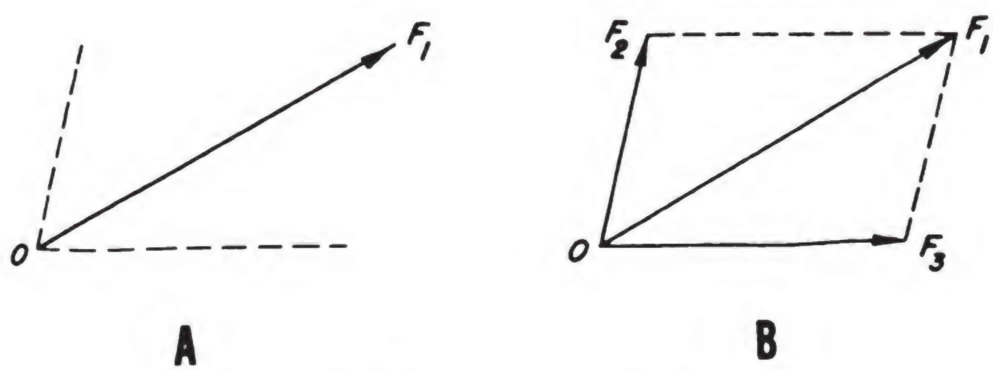

Figure 4–4.—Finding two components of a force.

to the two forces, the component forces are defined, as shown in figure 4–4B.

In figure 4–5, the force of the wind against the sail of a sailboat, represented as the force vector *R*, has been resolved into components. For simplicity, the sail is considered to be flat in this illustration. In figure 4–5A, *R* has been resolved into components *A* and *B*. *A*, parallel with the sail, produces little effect, but *B* acts on the boat through the mast. However, to find the force effect of *B* on the movement of the boat through the water, it is resolved, in figure 4–5B, into the components *C*, parallel with the keel of the boat, and *D*. *D* produces very little motion because the boat is not built to move sideways in the water. The component *C* represents the force producing forward movement of the boat by a wind blowing in the direction of the force vector *R*.

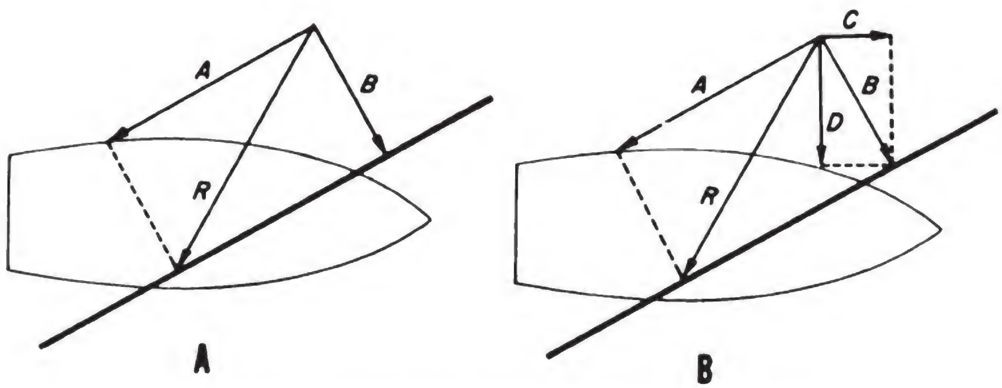

Figure 4–5.—Resolving a force vector into components.

Polygon of Forces

Up to this point, the effect of only two forces acting at a single point has been considered. Suppose that more than two forces are involved.

The resultant of more than two forces can be found by finding first the resultant of two forces and then using it with another component force to find another

resultant, etc. For example, in figure 4–6, forces *OA* and *OB* yield the resultant *OX*. Then a parallelogram is constructed using *OX* and force *OC*, which yields the resultant *OY*. Thus, *OY* is the resultant of *OA*, *OB*, and *OC*.

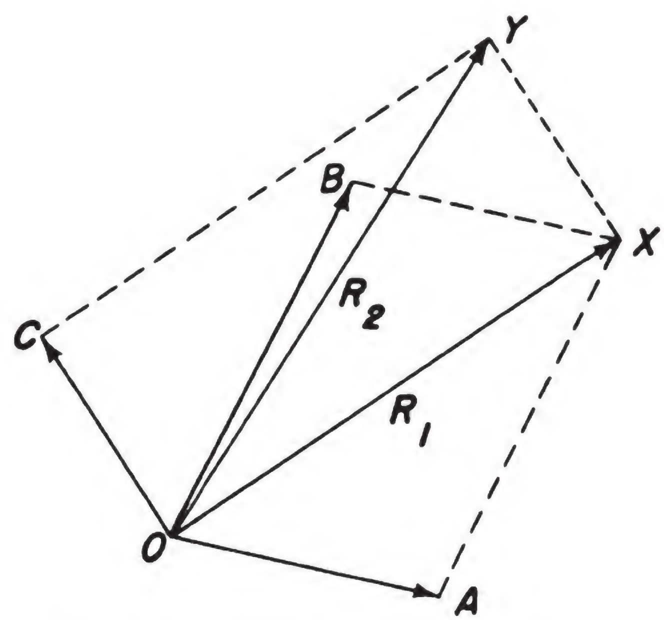

Figure 4–6.—Using the parallelogram construction to find the resultant of more than two forces.

However, as the number of forces increases, this method becomes increasingly complex. In its place, a polygon of forces is used. For example, take the three forces shown in figure 4–7 and, placing them tail to head, construct an open polygon, as shown in figure 4–7B. The arrow which closes this polygon, as shown in figure 4–7C, is the resultant of the forces in its proper length and direction.

Note that the resultant in figure 4–7 has its arrow pointing in the direction around the polygon opposed to that of the given forces. A force parallel and equal to this arrow acting at *O* represents the resultant in

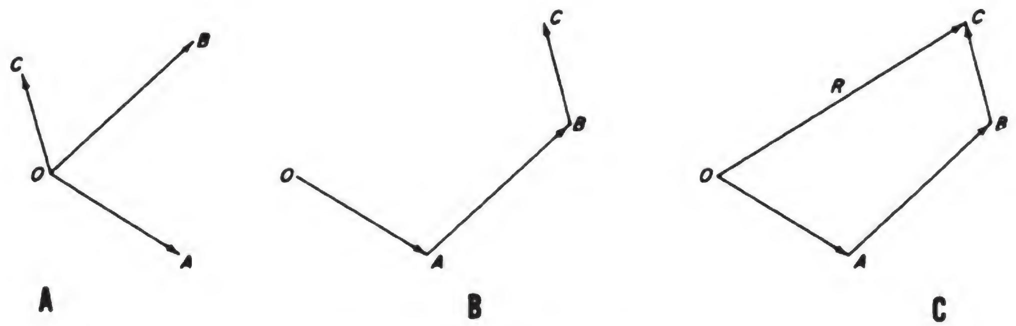

Figure 4–7.—Polygon of forces.

position, as well as in length and direction, as shown in figure 4–7C.

A problem in vectors can be solved graphically if it contains not more than two unknowns. These unknowns may be:

1. The magnitude and direction of one vector.
2. The magnitude of one vector and the direction of another.
3. The magnitude of two vectors.
4. The direction of two vectors.

Conditions of Equilibrium

Statics is that branch of mechanics which is the study of the equilibrium of forces. It is concerned with bodies at rest and the forces which keep them at rest. When an unbalanced force acts on a stationary object, the object will move, but that does not mean that there is no force involved when the body is stationary. Instead it means that the forces acting on the body are in balance. A picture hanging on the wall is stationary, but there are a number of forces acting upon it.

Suppose you are dealing with a structure in which the forces are in equilibrium. How would you represent these forces? Suppose that at one point on a stationary body three forces are applied as shown in figure 4–8A, and these forces are in equilibrium. That is, they cause no movement at the point of application of the forces.

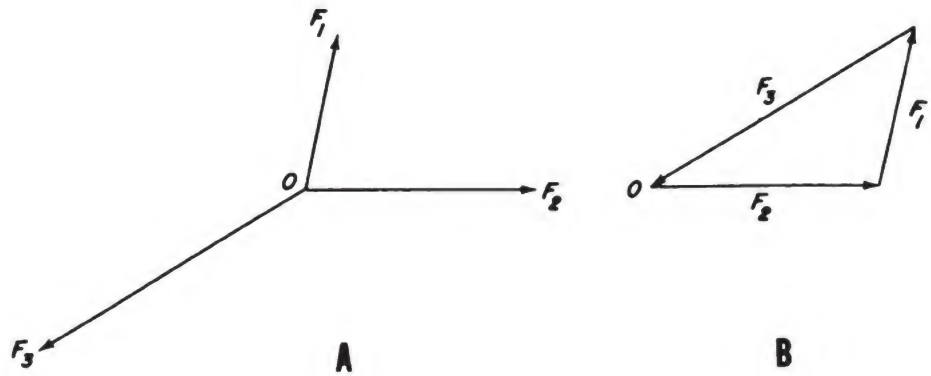

Figure 4–8.—Three forces in equilibrium.

You can solve this problem by drawing a triangle of forces, as shown in figure 4–8B. Since the forces are in equilibrium, force F_3 must be equal to forces F_1 and F_2, and the triangle must be a closed triangle. Now look at the side F_3 with side OA in figure 4–2 and with the diagonal OC of the parallelogram in figure 4–1. In other words, the EQUILIBRANT, a force which is sufficient to maintain equilibrium between forces, must be equal to the resultant of these forces and opposite in direction.

For example, the weight of a picture, which is equal to the pull of gravity upon it, is balanced by the tension in the cords by which it hangs on a nail in the wall. In other words, the sum of all the force vectors must equal zero, as shown in figure 4–9. When three forces acting on a body are not parallel, as shown in the figure, their lines of action must pass through a common point to produce equilibrium.

If more than three forces are involved, the force polygon may be used. If the forces act at O as shown in figure 4–10A, and they are in equilibrium, the polygon of forces will appear as shown in figure 4–10C. A closed polygon of forces, like a closed triangle of forces, represents forces in equilibrium. Look at figures 4–10 and figure 4–7.

The weight of a body can be considered to be a system of parallel forces acting on the body. When these forces

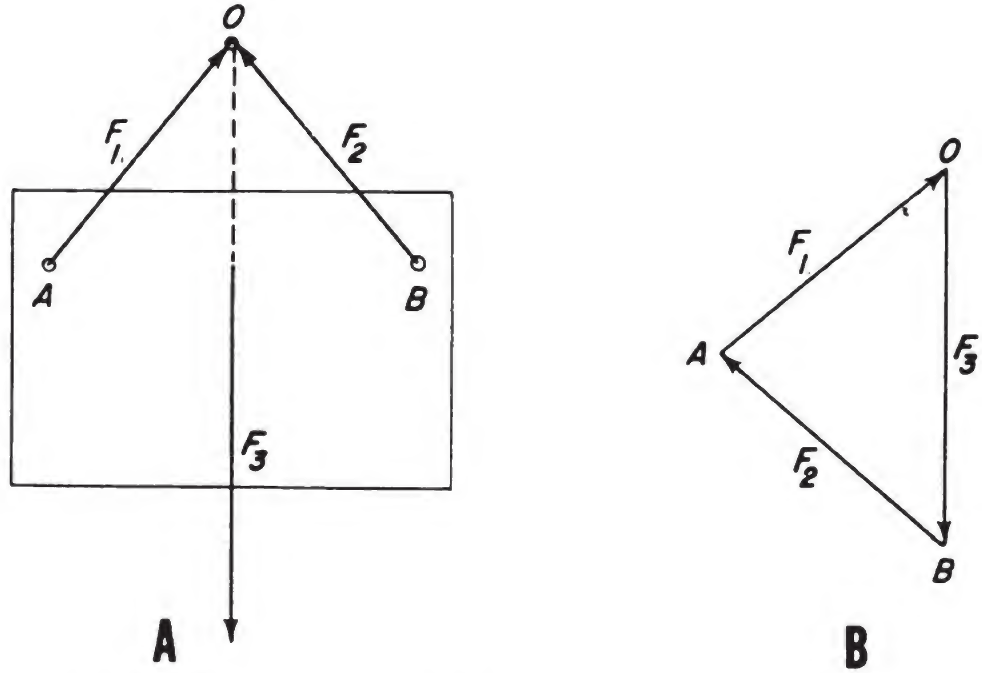

Figure 4–9.—Three nonparallel forces acting on a body to produce equilibrium.

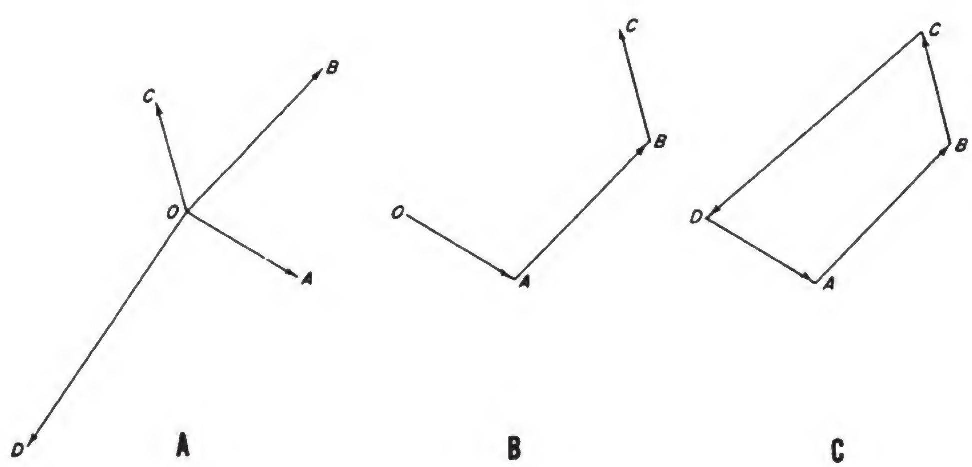

Figure 4–10.—Polygon of forces in equilibrium.

are replaced by a resultant, the point of application can be represented by a single force acting downward at the center of gravity, or CENTROID. When three or more parallel forces act on a body to produce equilibrium, the resultant of these parallel forces is equal and opposite to the equilibrant, as shown in figure 4–11.

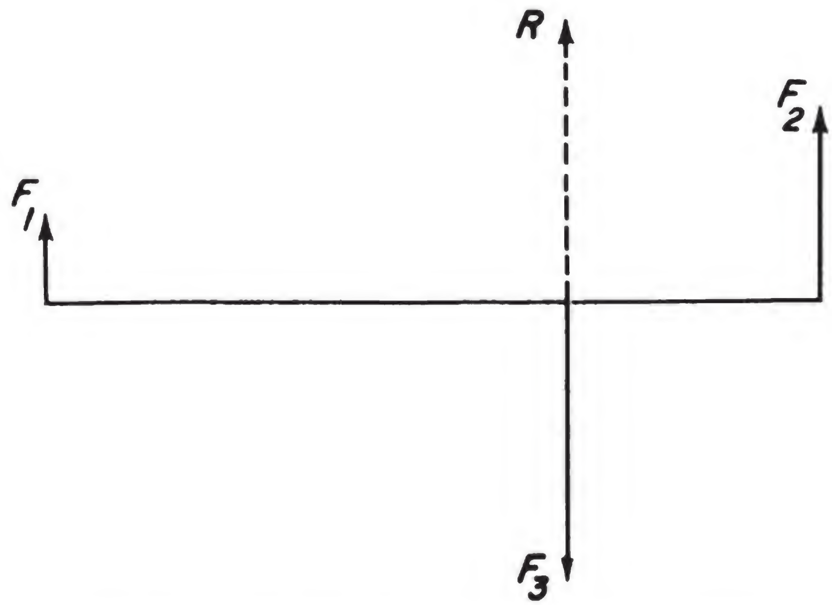

Figure 4–11.—Parallel forces acting on a body to produce equilibrium.

However, the forces acting on a body may be parallel, equal, and opposite, and still fail to produce equilibrium. In this case, the forces are acting at different points on the body. Such forces, producing a rotary motion, are called a COUPLE. (See fig. 4–12A.) The tendency to produce rotation is called the MOMENT of the couple, and it is measured by taking the product of one of the forces multiplied by the distance between the two, or the ARM of the couple.

In order to maintain equilibrium when a couple is acting upon a body, a second couple, consisting of two other equal and opposite forces, is required. The moments of the two couples must be equal and they must

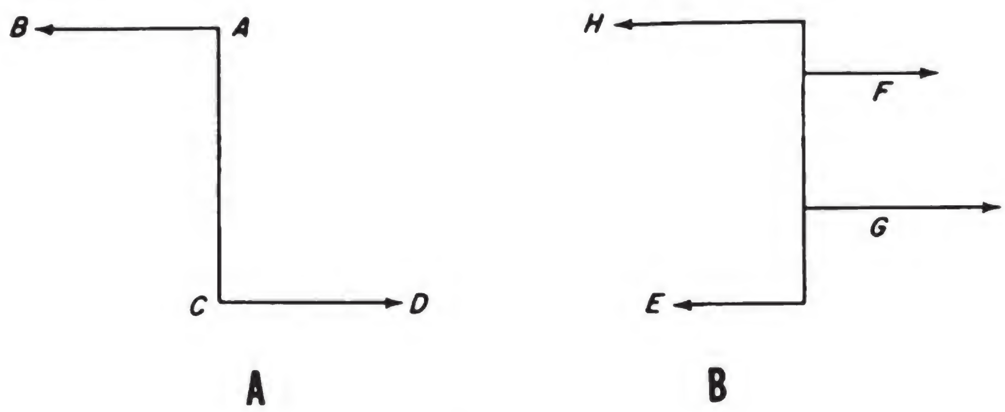

Figure 4–12.—A. A couple acts upon a body to produce rotation. B. Two couples acting upon a body may produce equilibrium.

tend to rotate the body in opposite directions. (See fig. 4–12B.)

Conditions for Stability

As has been stated, when forces act at different points on a body instead of at one point, they tend to cause rotation of the body. The tendency toward rotation caused by any force is equal to the force multiplied by its distance from the center of rotation. The center, or axis,

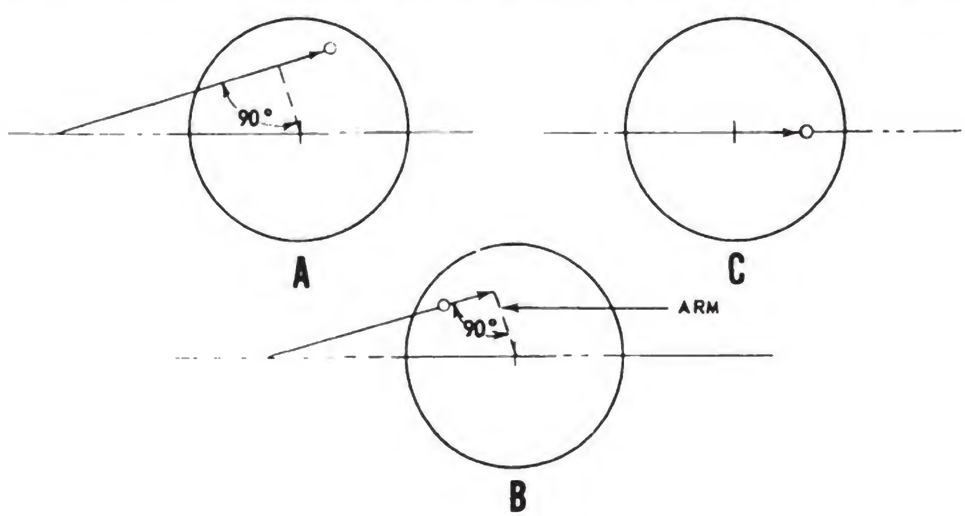

Figure 4–13.—A. The line of the moment, or torque, of a force is always perpendicular to the line of action of the force. B. Maximum moment. C. Minimum moment.

of rotation may be a stationary fulcrum as in the case of a lever, prybar, or seasaw, or it may be the center of gravity of the object, as in the case of the roll and pitch of a ship or airplane.

This product of force times distance from the axis is called MOMENT or TORQUE. It must be remembered that the moment arm is not necessarily measured from the point of application of the force but is always measured perpendicularly to the line of action of the force. (See fig. 4–13.)

For a body to remain in a stable condition, the sum of all horizontal forces must equal zero, the sum of all vertical forces must equal zero, and the sum of all moments must equal zero. Thus,

$$\begin{aligned} \Sigma H &= 0, \\ \Sigma V &= 0, \\ \Sigma M &= 0, \end{aligned}$$

in which the Greek capital sigma (Σ) represents the term SUM OF, H represents the horizontal forces, V represents the vertical forces, and M represents the moments. These three formulas may also be written

$$\begin{aligned} \Sigma F_x &= 0, \\ \Sigma F_y &= 0, \\ \Sigma M_o &= 0, \end{aligned}$$

in which F_x represents the X forces and F_y the Y forces in a system of rectangular coordinates, and M_o represents the moments.

MATHEMATICAL SOLUTION OF FORCES

The accuracy with which a resultant or an equilibrant can be determined by using vectors is limited by the accuracy with which the force diagram can be drawn. Greater accuracy can be achieved by using mathematics to find either of these quantities. In this section, the

trigonometric formulas which are used to solve problems involving the composition and resolution of forces will be explained briefly.

When the component forces form a right angle, the resultant may be found by the solution of a simple right triangle. For example, in figure 4–3, the resultant may be found graphically by drawing the two sides of the right angle and completing the triangle with the resultant.

The triangle can be solved using the following equation:

$$c = \sqrt{a^2 + b^2}.$$

When the component forces form an angle other than 90°, the resultant may be found by the solution of an oblique triangle. The two equations known as the LAW OF COSINES and the LAW OF SINES are used. The amount of the forces of the resultant is determined by the law of cosines and the angle of direction by the law of sines. The problem can also be solved by using the formula derived from these two laws.

In practice, however, it is usually easier to resolve all of the forces into rectangular components. When several forces are involved, each force may be resolved into its horizontal (H) component and vertical (V) component. Then add the components to determine the H and V components of the resultant. The horizontal component is equal to its magnitude multiplied by the cosine of the angle the vector makes with the horizontal. The vertical component is equal to the magnitude times the sine of the angle. Thus,

$$H = F_1 \cos \theta_1 + F_2 \cos \theta_2 + F_3 \cos \theta_3.$$
$$V = F_1 \sin \theta_1 + F_2 \sin \theta_2 + F_3 \sin \theta_3.$$

Remember that the Greek capital, sigma, means SUM OF. Thus, ΣH means the SUM OF ALL H VALUES.

The magnitude of the resultant is equal to the square root of the squares of its H and V components. Thus,

$$R = \sqrt{V^2 + H^2}.$$

The angle of the resultant with the horizontal is the angle whose tangent is the V component divided by the H component. Thus,

$$\tan \angle X = \frac{V}{H}.$$

When all the forces involved do not act in one plane, the rectangular coordinate system may be evolved into a three-dimensional system by the addition of a third rectangular axis. Such a system is shown in figure 4–14. In this case, the sum of the components along each axis must equal zero. However, most practical problems are in two dimensions or can be reduced to problems in two dimensions.

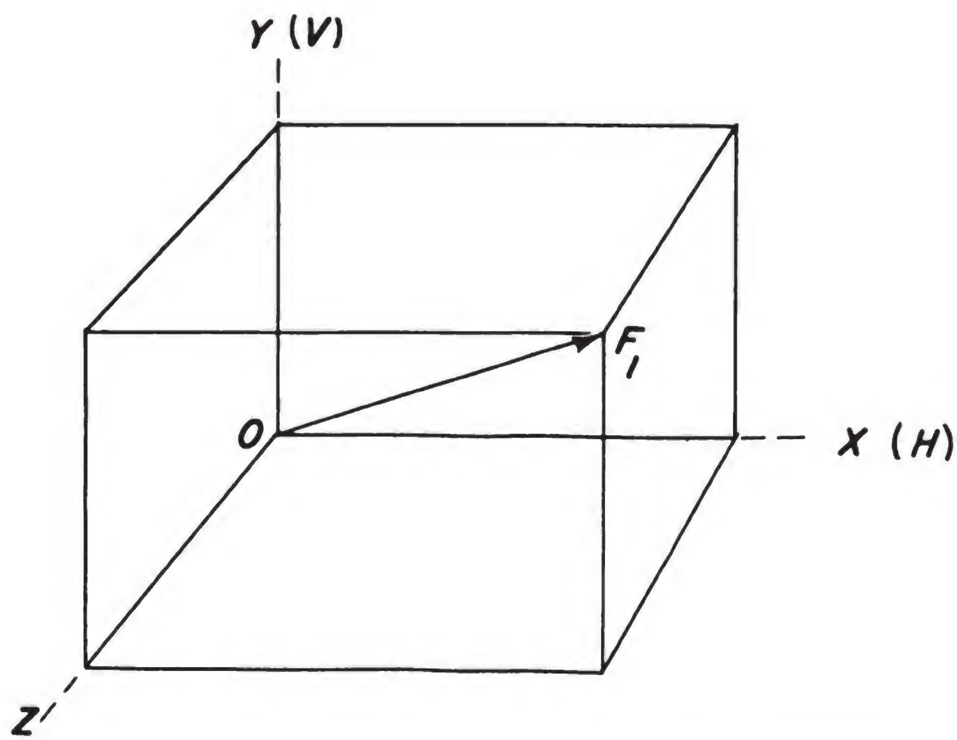

Figure 4–14.—Three-dimensional system for determining components.

For a more detailed discussion of statics and of the mathematical solution of forces than can be given here, read the USAFI text, MA 517, *College Physics*, which was formerly EM 466.

STRENGTH OF MATERIALS

All materials have certain technical properties, called MECHANICAL PROPERTIES, which can be measured or calculated. The basic mechanical properties consist of elastic limit, moduli of elasticity, ultimate strength, endurance limit, and hardness.

All materials have some elasticity. That is, a force applied to a material has a tendency to deform it. If the force is not too great, the material will return to its original state when the force is removed. The point at which the force becomes so great that the deformation in the material starts to become permanent is called the ELASTIC LIMIT of the material. This limit can be established for different materials by tests on specimens of the materials.

When a force is applied to a material, a resistance is set up in the material. This resistance is called the STRESS and is measured in terms of the units used to measure the force. In the English system of units, it is measured in pounds per square inch. The deformation which is caused in a material by the applied force is called the STRAIN, and is measured in inches. The ratio between the stress and the strain is called the MODULUS OF ELASTICITY.

The law of proportionality between stress and strain is known as Hooke's law and may be expressed by the formula

$$E = \frac{f}{e}$$

in which e represents the strain for 1 inch of length, f the stress in pounds per square inch, and E is the con-

stant representing the modulus of elasticity (measure of stiffness).

The point at which a material will break under an applied force is called the ULTIMATE STRENGTH. However, when a material is subjected to many repetitions of a load, it may fail by rupturing, even though the stress is below the elastic limit. The point at which this occurs is called the ENDURANCE LIMIT.

There is one more basic mechanical property of materials which can be determined by tests, and that is hardness. Hardness is actually a relative characteristic, and there are several methods of measuring it. Various tests for hardness of materials are discussed in *Draftsman 2,* NavPers 10473.

Deformation and Stress

Deformation, or strain, in a member may be longitudinal, that is, a lengthening or shortening of the body, or it may be angular, producing a change in the angle between the faces of the member. According to the *Handbook of Applied Mathematics,* which was originally prepared by Jansson, there are five kinds of stresses:

"1. Tensile stres, or pull, is a force which tends to elongate a piece of material.
2. Compressive stress, or push, is a force which tends to shorten a piece of material.
3. Shearing stress is a force which tends to force one part of a piece of material to slide over an adjacent part.
4. Torsional stress, a form of shearing stress, is a force which tends to twist a piece of material.
5. Transverse stress, a combination of tension and compression, is a force which tends to bend a piece of material."

Stress-Strain Diagrams

When tests are made of the reactions between loads and deformations on specimens of material, the results are

presented in diagrams which are called stress-strain diagrams. These diagrams are plotted using stresses as ordinates and deformations as abscissas, whether the stress is tensile or compressive. In figure 4–15, such a diagram is shown.

When a load is applied to a specimen, the deformation is directly proportional to the stress up to the point shown as *e* in the diagram, and this point defines the elastic limit of the material. At any point to the left of S_e, the specimen will return to its original size and shape. Beyond S_e, some deformation will remain, even after the

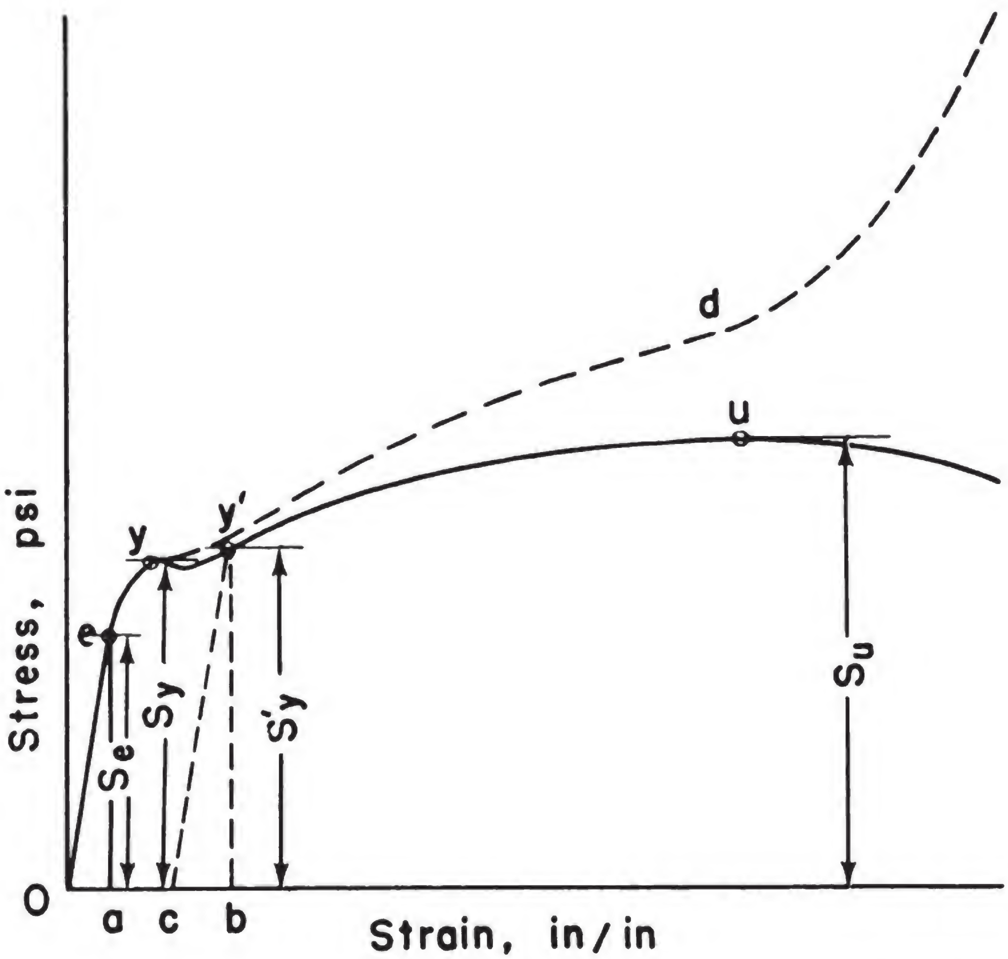

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Figure 4–15.—Stress-strain diagram.

load is removed. However, there is a point very close to S_e which is not shown in this figure, but which defines the proportional limit. That is, strain remains proportional to stress after the elastic limit is reached, but this point of proportional limit is so close to that of the elastic limit that the two are usually considered equal.

Any increase of stress above this point is accompanied by a greater increase of deformation up to point y. At this point a sudden and large increase of deformation occurs without any increase in the load. This is the YIELD POINT.

The point u at the top of the curve, represents the ULTIMATE STRENGTH of the specimen. Beyond this point, the material begins to fail. What is called NECKING occurs, and the material finally breaks. The breaking point varies but, in the same material, the position of u will not vary greatly.

Notice that the direct proportion between stress and strain shown as O to e on the curve is a straight line in this diagram. The tangent of the angle which this line forms with the abscissa of the graph is numerically equal to the modulus of elasticity and Hooke's law may be restated thus,

$$E = \frac{f}{e} = \tan \alpha.$$

In diagrams for those materials which show no direct proportion between stress and strain, this portion of the line is a curve and the modulus of elasticity varies as the slope of the tangent of the angle. However, since a narrow range of working stresses is used for these materials, the curve is sufficiently close to a straight line so that the tangent of the angle may be used.

Secondary Mechanical Properties

From the tests for the basic mechanical properties of materials, secondary characteristics may be deter-

mined which are also important in construction and design. These are resilience, toughness, ductility, and brittleness.

RESILIENCE means that when outside forces act upon a material to create internal stress, it absorbs the energy. When this stress is released, the material gives up the potential energy. Resilience is the capacity to absorb energy without permanent deformation. TOUGHNESS is the capacity to absorb excessive energy in a single application of a force.

BRITTLENESS and DUCTILITY are opposite qualities. A material, such as steel or timber, which has the quality of warning of impending failure through a noticeable deformation is called ductile. A material which fails without first indicating impending failure, such as cast iron or concrete, is a brittle material.

Types of Loads

When a structure or a machine part is to be designed, different properties of material may be required in different members to meet varying conditions. The types of loads which these members must bear determine the mechanical properties necessary in the materials, as well as the size and shape of the members.

Loads may be either what is called DEAD or LIVE. Dead loads consist of STATIC, or steady, loads. Live loads may be IMPACT, or shock, loads or they may be REPEATED loads, which cause variable stresses. They may also be a combination of one or several of these types.

Design Criteria

As a draftsman, you are not required to design or to understand design criteria. However, it may be of interest to you to learn something about the steps involved in design and the terminology.

When a machine is designed, the first step consists of selecting the proper kinematic arrangement or mechanism. When a structure is designed, its use is of first

importance. The second step consists of solving the energy and force problems involved. In such solutions, statics is used, and the problems may be solved either mathematically or graphically.

The third step in design consists of designing the members so that undue distortion or breakage does not occur under the loads carried. For this purpose, the various properties of materials must be considered and also the shape of the members, since the greatest concentration of material should be in the direction in which the greatest force is exerted. In line with this, it will be found that hollow members may often be as strong as a solid shaft, and that designing a member so that it is hollow serves to conserve material and make the handling of the member easier.

Distortion in members can be decreased by the proper distribution of materials. In the design of girders, an effort is usually made to get the most use of the steel for the least concentration of it, both in order to conserve material and in order to simplify the handling and shipping of the girders. For example, if a square bar were to be used to hold up a certain structure, a comparatively large bar would be necessary. However, with the proper geometrical distribution of the steel, the same stiffness can be obtained with considerably less material. Also, if a smooth sheet of aluminum were to be used as a covering for a roof, the thickness and cost of the material would be unreasonable. However, if the aluminum sheet is corrugated, a thin sheet will withstand the same stresses as the thick sheet.

Criteria for the strength of materials can be found in most handbooks, such as those listed in appendix III in this book. The field is a very broad and complex one, and the material included here is a very brief introduction to it.

QUIZ

1. What is force?
2. What actions occur when work is done?
3. What are the two groups in which quantities can be classified?
4. Give four examples of types of vector quantities.
5. What is the force called which represents two or more forces acting on a particle?
6. When only two forces are acting on a particle, what two graphic methods may be used to find the resultant of the two forces?
7. When a known resultant is broken down into a number of forces, what are these called?
8. When more than two forces are involved, what method is used to find the resultant?
9. Under what condition can a problem in vectors be solved graphically?
10. Define statics.
11. How does a triangle of forces in equilibrium differ from a triangle of forces which are not in equilibrium?
12. What is a centroid?
13. What is a couple?
14. How is the moment of a couple measured?
15. What are the three formulas which define the conditions for equilibrium?
16. When the component forces form a right triangle, the resultant may be found by solving the triangle using what equation?
17. In practice, how are the component forces which form an angle other than 90° usually solved mathematically?
18. What is the elastic limit of a material?
19. What is the deformation which is caused in a material by an applied force called?
20. What is the resistance set up in the material by an applied force called?
21. What is the ratio between stress and strain called?

22. Define ULTIMATE STRENGTH and ENDURANCE LIMIT.

23. Why are the mechanical properties of materials important in machine design?

24. What are the different types of loads?

CHAPTER 5

MACHINE DRAFTING

INTRODUCTION

Your job as a DMM 1 or a DM 1 will be to make layouts of machine parts from sketches or design drawings. Aboard repair ships or at advanced bases, most of the drawings with which you will be concerned will be adaptations of existing drawings. On repair ships, you will have access to prints of manufacturers' drawings and BuShip's drawings. Ashore, prints of Bureau drawings, A–E (architect-engineer) drawings, and manufacturers' drawings are available. When a part is broken, it may be necessary to make a drawing so that the part may be rebuilt. In actual practice, you will find that draftsmen may perform more advanced work when it is required, and opportunities abound for valuable experience. In any case, you need to have some background in the methods used, as well as an understanding of the shapes and functions of various machine parts.

When a machine part is designed, the first step consists of planning the kinematic arrangement or mechanism. Next, the dimensions must be determined so that the part will be strong enough, sufficiently rigid, and resistant to wear. Then the forces which will be brought to bear on it must be determined and the proper stress

formulas, and the applicable factors and coefficients, selected. Finally, materials with physical properties which will withstand such stresses must be selected, with cost a vital consideration.

The specifications for the various materials stocked by the Navy are listed in alphabetical order in the *Index of Specifications and Standards (used by) Department of the Navy, Military Index*, Volume III, NavSandA Publication No. 62. If these specifications have been kept on file at your ship or station, you need only locate the specifications for any material by number. If not, you may have to request that a copy of the correct specification be ordered.

When you begin a layout, it is wise to become familiar with the types of materials, bolts or screws, or similar items available in the bins at the machine shop of your ship or at your station. Often such materials can be used, instead of others that would have to be ordered, and valuable time can be saved when the machine part is made. Also, it may help to talk a design over with the man who will work on the part to be sure the dimensions and finishes can be met.

DESIGN LAYOUT

The design layout is usually classified as a type of assembly drawing. The layout may be developed through a slow process, starting with a few given dimensions and requirements and progressing until the complete shape and size of the machine or machine element has been defined. It is actually a graphic solution of a problem.

Since the layout serves as a means of finding certain dimensions, it must be a precision drawing. When the drawing is completed, it should be possible to measure the drawing itself in order to find the dimensions which will be given on the detail drawing. Some authorities maintain that the measurements on design layouts should be accurate to within $1/100$ inch.

Actually all detail drawings should be made with as great a precision as possible, because a good drawing inspires confidence and the workman using it will be more likely to do good work on the part he makes with the incentive supplied by a good drawing. However, there are certain techniques which are specifically applicable to layouts. For example, layouts should always be made to as large a scale as possible because of the accuracy required.

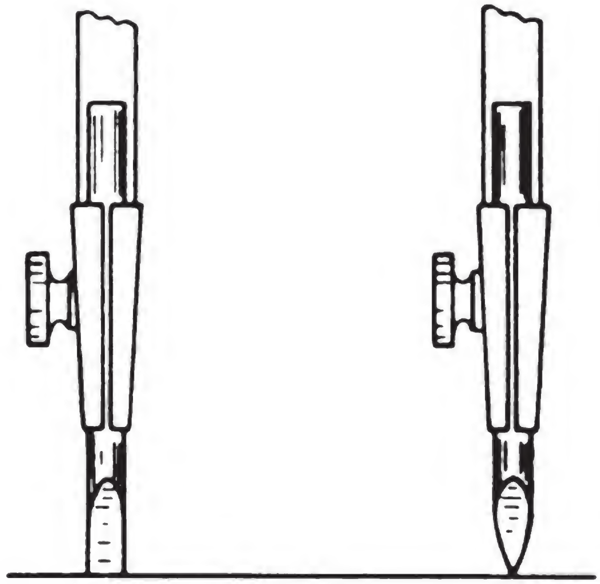
In order to make the layout lines, you must use a very sharp pencil. Remove the wood until about ½ inch of lead is exposed. Grind the lead to a conical point on a sandpaper pad, rotating the pencil as it moves across the pad. In order to keep the lines the same, you will have to continually repoint the lead on the pad as you work. As you draw a line, rotate the pencil slowly about its own axis to prevent the lead from flattening as it wears. Draw the pencil across the paper with a full arm movement. Arm motion is necessary to produce true lines.

Some men feel that when they do a layout, it is better to stand, rather than to sit on a stool. In general your eyes should be directly above the area on the drawing on which you are working.

On layouts, measurements should always be made along a drawn line. For this reason, layout lines are not drawn to a given length, but when the position and direction of such a line has been determined, it is drawn past the point where an intersection or a measured point may be expected to fall. Measurements should be recorded with a needle point. Do not enlarge the holes made, but encircle them with a light freehand line so that they can be found readily.

When you use a compass, it is necessary to use the same lead you use for the other lines on the layout if they are to be the same weight. Instead of using the leads that come with the compass, cut a length of lead from the same type of pencil you are using for the other lines. It

will be easier to obtain the same point if you sharpen the lead to a long conical point before you cut it from the pencil.



Deane Lent "Machine Drawing" (copyright, 1951, by Prentice-Hall, Inc., Englewood Cliffs, N. J.), p. 280. Reproduced by permission of the publisher.

Figure 5–1.—Sharpening the lead for the compass; avoid the wedge point.

Since it is not possible to rotate the lead in the compass, some provision must be made to keep it from wearing and causing the line to widen as you draw it. This can be done by flattening the side of the lead. A broad wedge shape, however, should be avoided. (See fig. 5–1.) Remember that you will have to keep continually repointing the lead as you work.

CAM LAYOUT

A cam is usually a rotating plate or cylinder which produces reciprocating motion in its follower. It pro-

vides a means of obtaining many unusual and irregular motions that would be difficult to produce otherwise. The principle on which it operates is simple. A rotating shaft carries the cam. The rotation of the cam causes the follower to reciprocate with a motion which is determined by the shape of the cam profile.

A number of different types of cams are shown in figure 5–2. The type varies to fit different machines and methods. In each case, the profile of the cam is designed to produce a required motion. In cam design, care must be taken to be sure that the cam will drive easily.

It is your business to know how to go about the laying out of a cam, but this does not mean that you will be held accountable for the specific details of different types of cams. If you have a cam to lay out, cam drawings will very likely have been made previously at the activity where you work. Obtain copies of these and study them before you make your layout. If you have access to the shop where the cam will be made, the men in the shop can help you determine which dimensions are important.

Types of Motion Produced by Cams

Cams produce two basic types of motion. The first is uniform and the second variable. With uniform motion, the cam starts suddenly and maintains the same velocity until it stops just as suddenly. For example, if a train were to start suddenly from one place at 40 miles an hour, travel a given distance at the constant rates of 40 miles an hour, and stop abruptly, you would have uniform motion. The fast start and stop involved produce considerable shock. For this reason, a cam designed to move with uniform motion requires a powerful mechanism to move it and is used only to move light objects.

Cam diagrams may be plotted on coordinate paper, showing the type of motion. A diagram of uniform motion is shown in figure 5–3. The cam position is shown on the abscissa in terms of the degrees of revolution, and the follower position is shown on the ordinate in terms

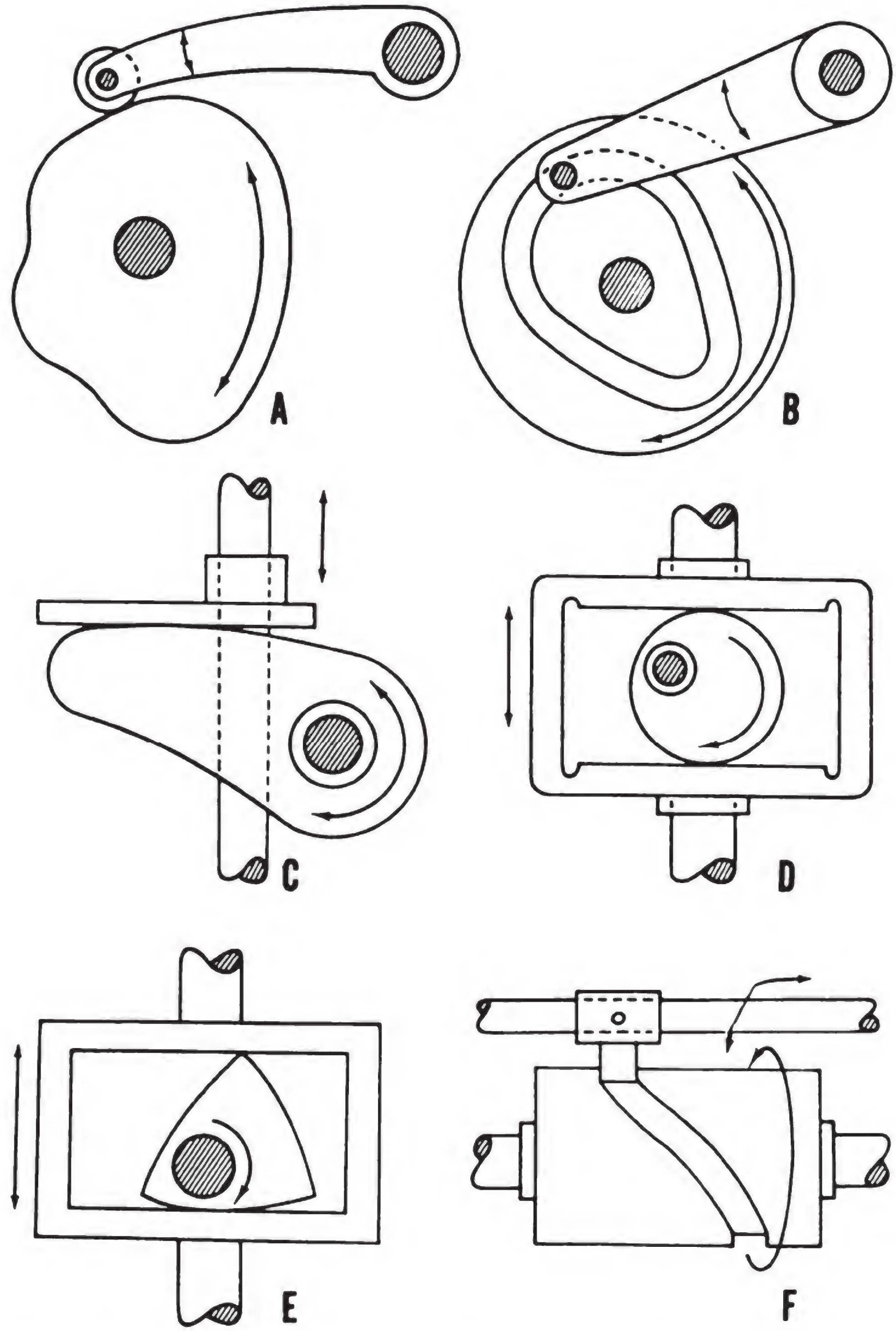


Figure 5–2.—A plate cam with roller follower on a rocker arm, designed to produce irregular motion. B. Face cam. C. Cam with flat follower. D. Scotch yoke. E. Triangular cam. F. Cylindrical cam.

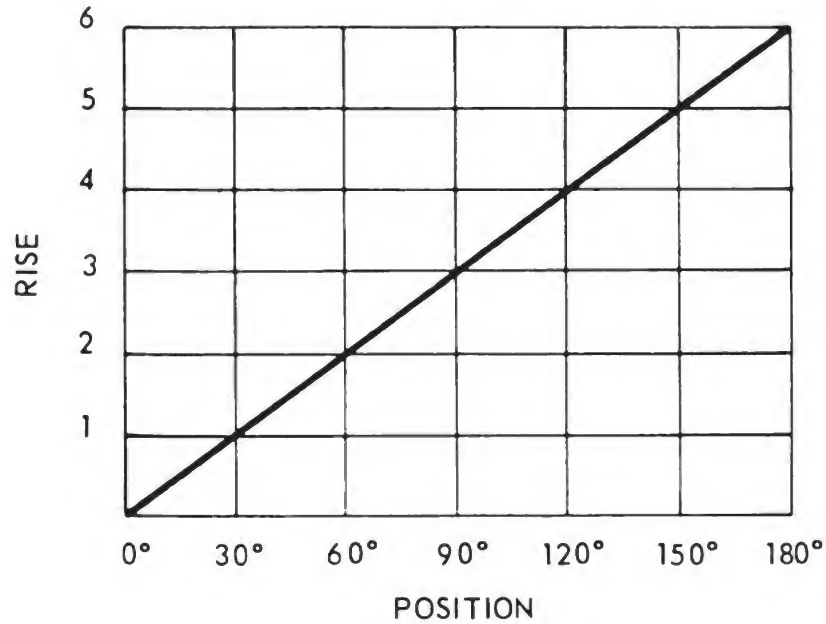


Figure 5–3.—Diagram of uniform motion.

of intervals of rise. If the cam rotates at a uniform velocity, each segment of rise is covered in the same time.

With variable motion, instead of uniform motion, the cam starts and stops gradually with little or no shock. There are three types of variable motion. One of these is a modified uniform motion. This merely means that the cam is designed to produce uniform motion except at the beginning and the end, where it is modified so that the motion becomes more gradual, resulting in less shock. A diagram of this type of motion resembles a diagram of uniform motion except that a radius is shown at the start and again at the end of the movement. (See fig. 5–4.)

With harmonic motion, a second type of variable motion, the movement is slow at first, increasing to a maximum at the center, and decreasing until it comes to rest at the end. Harmonic motion is the type shown by the sine curve. It can best be developed graphically as shown in figure 5–5.

If an object is considered to start at a point, and move around a semicircle, covering each segment of the semi-

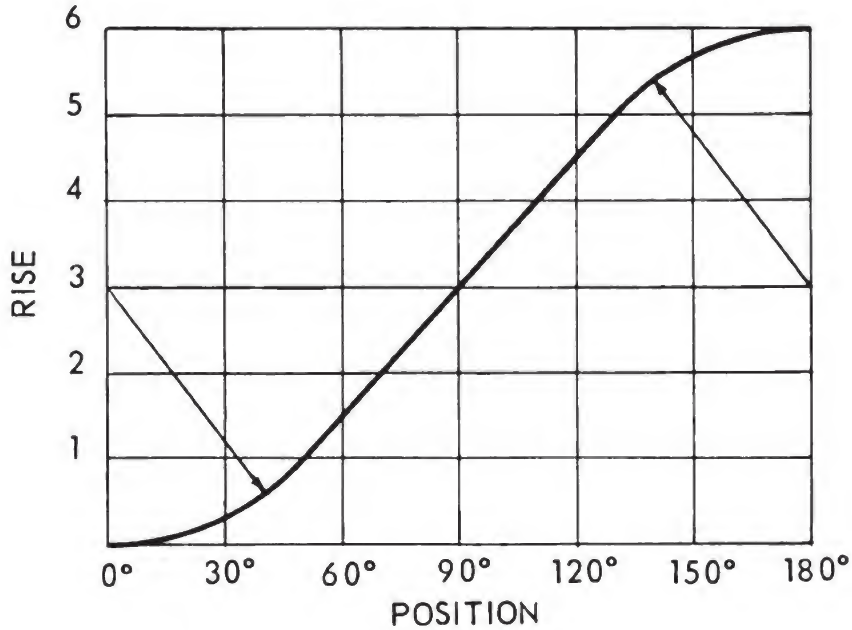


Figure 5–4.—Diagram of modified uniform motion.

circle in the same length of time, and a second object is considered to start at the same point and move along a straight line, keeping exactly even with the first object, the resulting motion of the second object is called har-

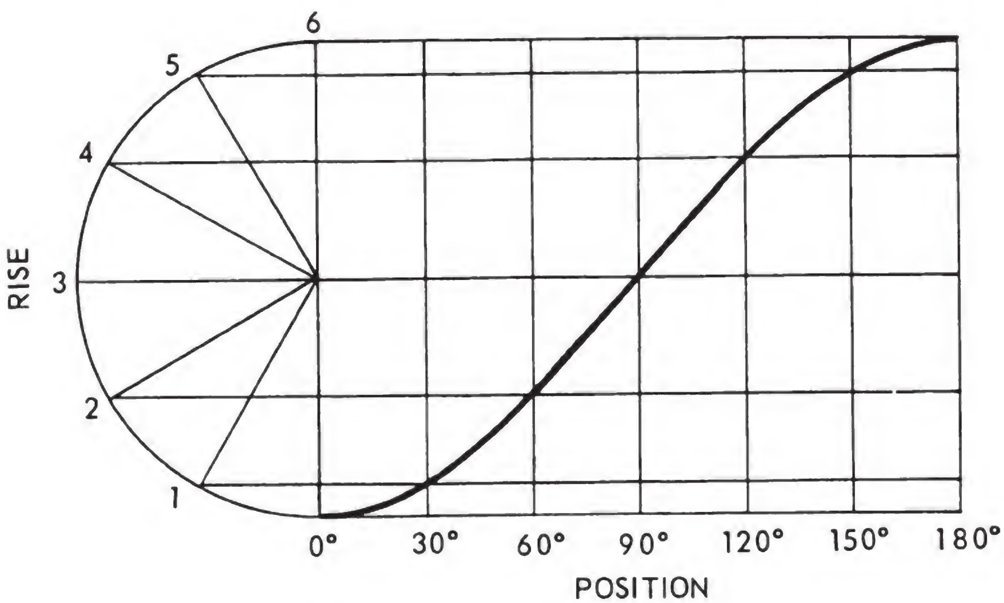


Figure 5–5.—Harmonic motion diagram.

monic motion. It will start out slowly, accelerate until it reaches a maximum, and then decelerate until it comes to a stop. To prove this, the semicircle has been divided into six equal arcs, and lines perpendicular to the straight line have been dropped from the ends of these chords. Note that the spaces between the divisions on the straight line increase to the center and then decrease to the end.

Another type of variable motion is a constantly accelerated and retarded motion. (See fig. 5–6.) Mathematically this is a parabolic curve, where the rise is directly proportional to the square of the degrees of revolution. If the cam velocity is constant, the distance traveled by the follower is directly proportional to the square of the time. Thus, the total rise is proportional to 1^2, 2^2, 3^2, or 1, 4, 9, from the beginning. This may be expressed in terms of the distance between points rather than for the beginning, or as 1, 3, 5, since $1 + 3 = 4$ and $4 + 5 = 9$.

In order to divide the line of the ordinate for a constantly accelerated and retarded motion, draw a line at any angle and divide this line into the total number of points to be included in the rise, as shown in figure

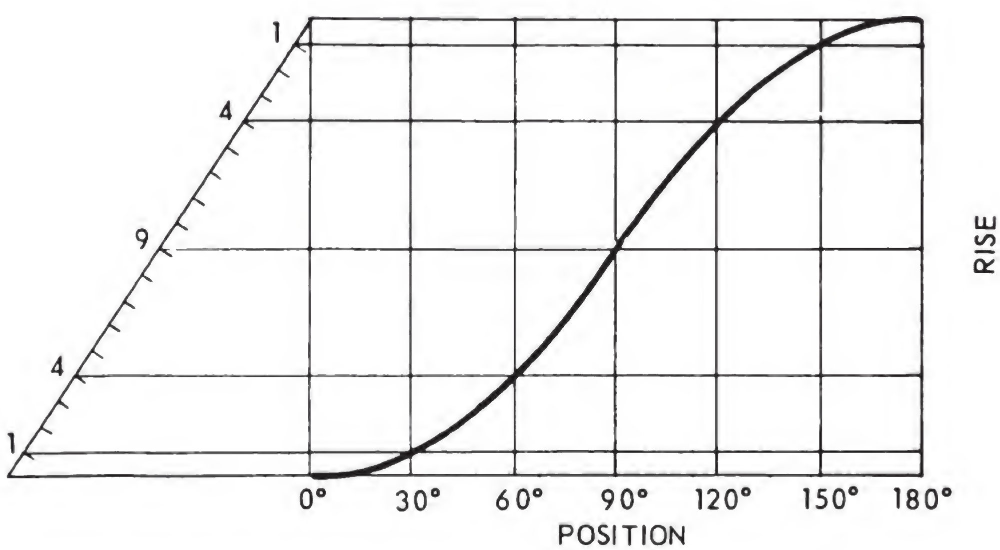


Figure 5–6.—Diagram for a cam with a follower that moves with a constant acceleration and retardation.

5–6. In this particular case, 1, 3, 5, 5, 3, 1 are added to give 18 as the total number of points, or 9 and 9 are added, which is the same thing, to give the 18.

From the point marking the 18th division, draw a line to the end of the ordinate. Parallel with this line, draw a second line from the first division point to mark the first division of rise in the ratio. Then count off these divisions and draw a third line parallel with the end line, and so forth until all the divisions in the required ratio have been marked on the ordinate.

Layout of a Plate Cam

With the plate cam described here, the cam is machined to a shape so that the follower will rise with harmonic motion and fall with uniform motion.

Suppose that a layout is to be made of a cam with the following characteristics. The cam turns in a counterclockwise direction, or to the left. It raises the follower roller 1½ inches with harmonic motion while it turns through an arc of 150 degrees. The follower then drops ¼ inch and rests during 30° of turn and finally returns to its original position as the cam turns through the remaining 180 degrees with uniform motion. The centerline of motion of the follower is 1 inch to the right of the cam axis. The centerline of the roller is 1½ inches radially from the cam center. The diameter of the roller is 1 inch.

As a preliminary step to making the layout, draw a displacement diagram, as shown in figure 5–7. The vertical scale of this diagram shows the 1½ inches of rise of the cam follower to scale. The horizontal scale shows the 360° of the circle of the cam face and may be drawn to any convenient scale. The 150° interval of rise of the cam follower is divided into six portions, the ¼ inch drop is shown to scale, and the 180° interval of fall is also divided into six. Note that, in the displacement diagram, it is obvious that the follower rises faster than it falls.

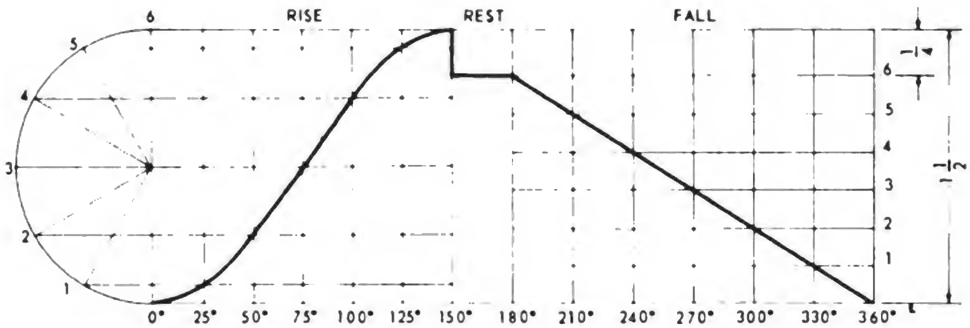


Figure 5–7.—Displacement diagram for a plate cam.

Next, start drawing the layout of the cam by locating the cam and follower.

1. Draw the horizontal centerline of the cam and, through its center, the vertical centerline, as shown in figure 5–8A.

2. Measure off 1 inch to the right of the vertical centerline of the cam to find the centerline of motion of the follower, and draw a vertical line marking it.

3. Next find the lowest position of the follower roller by measuring 1½ inches radially from the center of the cam to the centerline of motion of the follower. (See fig. 5–8A.) The point found is the center of the follower roller at the lowest position.

4. Find the center of the follower roller at its highest position by measuring from the center of the lowest position upward 1½ inches on the vertical line of its motion.

5. Draw a circle of the follower roller in both of these positions, using the points just found as centers, and a radius of ½ inch (half the 1-inch diameter of the roller) as shown in figure 5–8A.

6. With the center of the cam as a center, draw the base circle of the cam itself by describing a circle, which is tangent to the circle of the follower roller in its lowest position.

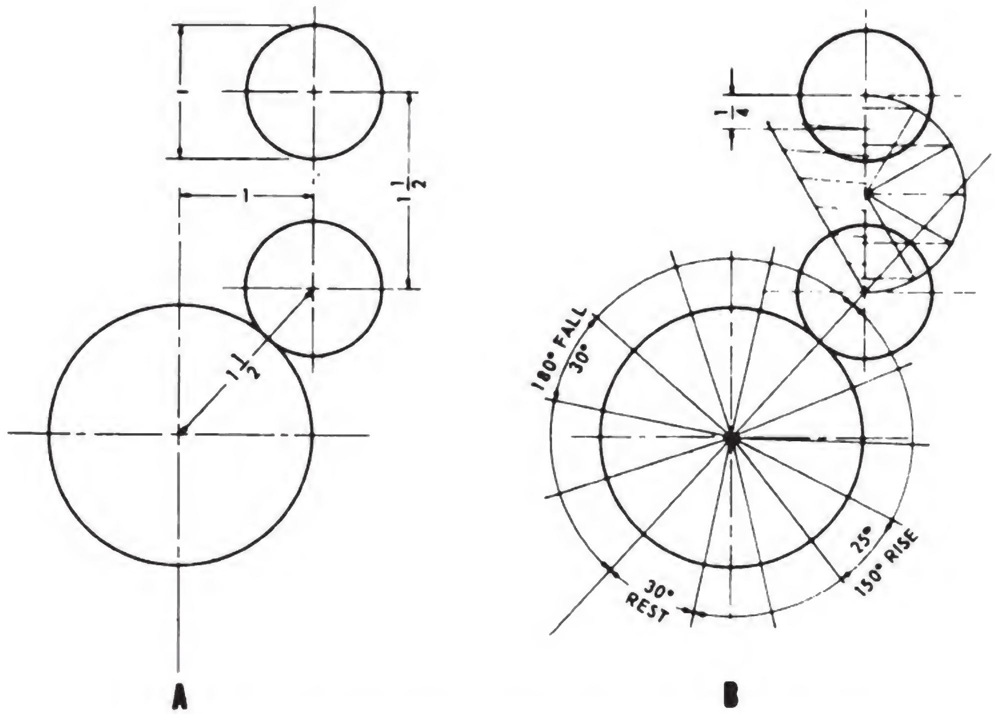


Figure 5–8.—The beginning of a layout for a simple plate cam.

7. Next draw a semicircle from the center point of the follower roller at the lowest position to the center point at its highest position, as shown in figure 5–8B. Divide this semicircle, as shown, into six equal arcs, and draw lines perpendicular to the line of rise of the follower roller from the ends of these arcs. The follower roller must pass through each of the points found on its centerline of motion in the same time interval during the rise, in order to produce harmonic motion, and again, although with a different time interval, during the fall.

8. Divide the base circle of the cam into the arcs of 150° rise, 30° rest, and 180° fall. Since the cam turns to the left, the arc of rise will be to the right of the follower roller at its lowest position and the arc of fall to the left. A line drawn through the center of the follower roller at the lowest position to the center of the cam and continued to the outer circumference of the base cir-

cle defines the 180° of the arc of fall. A line drawn through the center of the cam at an angle of 30° to the first line, as shown in figure 5–8B, defines the arcs of rest and rise.

9. In order to develop the arc of rise for the cam, it must be divided into the same number of divisions as the line of motion of the follower and on the cam these will be equal divisions. Divide the 150° of the arc of rise by 6 and, draw lines from the center of the cam extending beyond the base circle and defining each 25° segment of the arc of rise. (See fig. 5–8B.)

10. Now on the line of motion of the follower roller, mark off the 1/4 inch of drop. The remaining 1 1/4 inches should be divided into 6 equal spaces. In order to do this, a slanted line has been drawn and divided in figure 5–8B, and the division points transferred to the line of motion of the follower roller.

11. Divide the 180° of the arc of fall by 6 and draw the lines defining the 30° segments as shown in figure 5–8B.

12. From the center of the cam, draw arcs through the points on the line of motion of the follower which were defined by the harmonic motion diagram. Extend these arcs to the six lines from the center of the cam which lie in the 150° of rise, as shown in figure 5–9, and to the extension of the line drawn from the center of the cam to the center point of the follower roller in its lowest position. (As you will see, the angle between this line extended and the line of motion of the follower roller is used to compensate for the offset of the follower roller.)

13. The fact that the line of motion of the follower is offset complicates the design. Note that on two arcs to lines from the center of the cam, arrows are drawn defining the center of the follower roller in relation to the lines from the center. (See fig. 5–9.) This is the compensation for the offset of the follower roller. Note that in each case, the segment of the arc defined by the arrow equals the segment of the same arc which falls in the

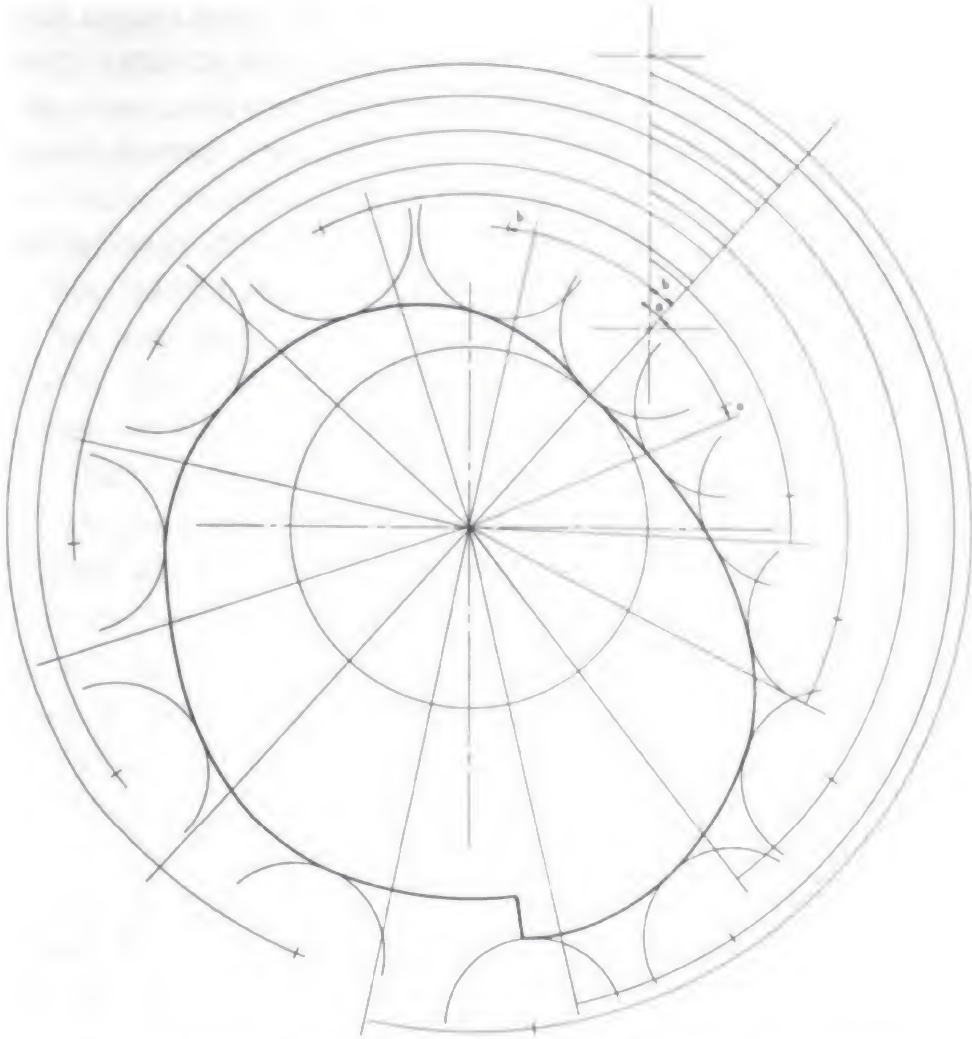


Figure 5–9.—Final steps in drawing the layout of a simple plate cam.

angle between the line of motion from the follower roller and the line from the center of the cam which passes through the center point of the follower roller in its lowest position. If the line of motion of the follower roller were in line with the centerline of the cam—that is, if there were no offset—it would not be necessary to compensate in this manner.

14. For example, to locate the roller positions on the arc of rise of the cam, first set the dividers to a distance equal to the chord *a*, as shown to the right of the line of

motion of the follower roller, and step off this distance on the arc above—that is, to the left of—the radial line 1 in the arc of rise. Circle the point found so that it will be easy to locate again. Proceed in the same way until all the centers for the follower roller are found for the arc of rise. (See fig. 5–9.)

15. To locate the roller positions on the arc of fall, a similar procedure is followed. For example, set the dividers to a length equal to the chord *b*, and step off this distance on the arc below—that is, to the left of—the radial line 1 in the arc of fall. Proceed until all the centers for the follower roller are found on the arc of fall.

16. Using a radius of ½ inch and the centers just found, draw the arcs representing the side of the follower roller in relation to the cam as it rotates. (See fig. 5–9.)

17. Finally, develop the contour, or shape, of the cam by drawing a line tangent to the arcs of the follower roller, using a french curve. (See fig. 5–9.) Since the shape of the cam must be a smooth curve, great care should be exercised in using the french curve.

After the layout is completed, it is wise to test the cam. Trace the completed layout on a piece of tracing cloth or paper and lay this over the original drawing, with the center of the cam on the tracing exactly coinciding with the center of the cam on the original drawing. Place a pin through these centers. Then rotate the tracing to the left, or counterclockwise, the direction in which the cam is to rotate. Note carefully, as you rotate the tracing, whether the center of each of the arcs representing the follower roller in contact with the contour of the cam, as shown on the tracing, matches the corresponding point on the vertical line of motion of the follower roller, as shown on the original drawing.

One more step may be necessary in making a layout of a cam. This consists of finding the pressure lines of the follower on the contour of the cam at each of the positions defined by the layout. These lines are normals.

That is, each of the lines is perpendicular to the curve of the cam at the exact point of tangency with the arc of the roller, as shown in figure 5–10. The arrows shown at the ends of the pressure lines indicate the direction of pressure in relation to the cam.

In order to make a detail drawing of this cam, it would be necessary to add a hole, keyway, and hub, and to show the necessary dimensions and specifications.

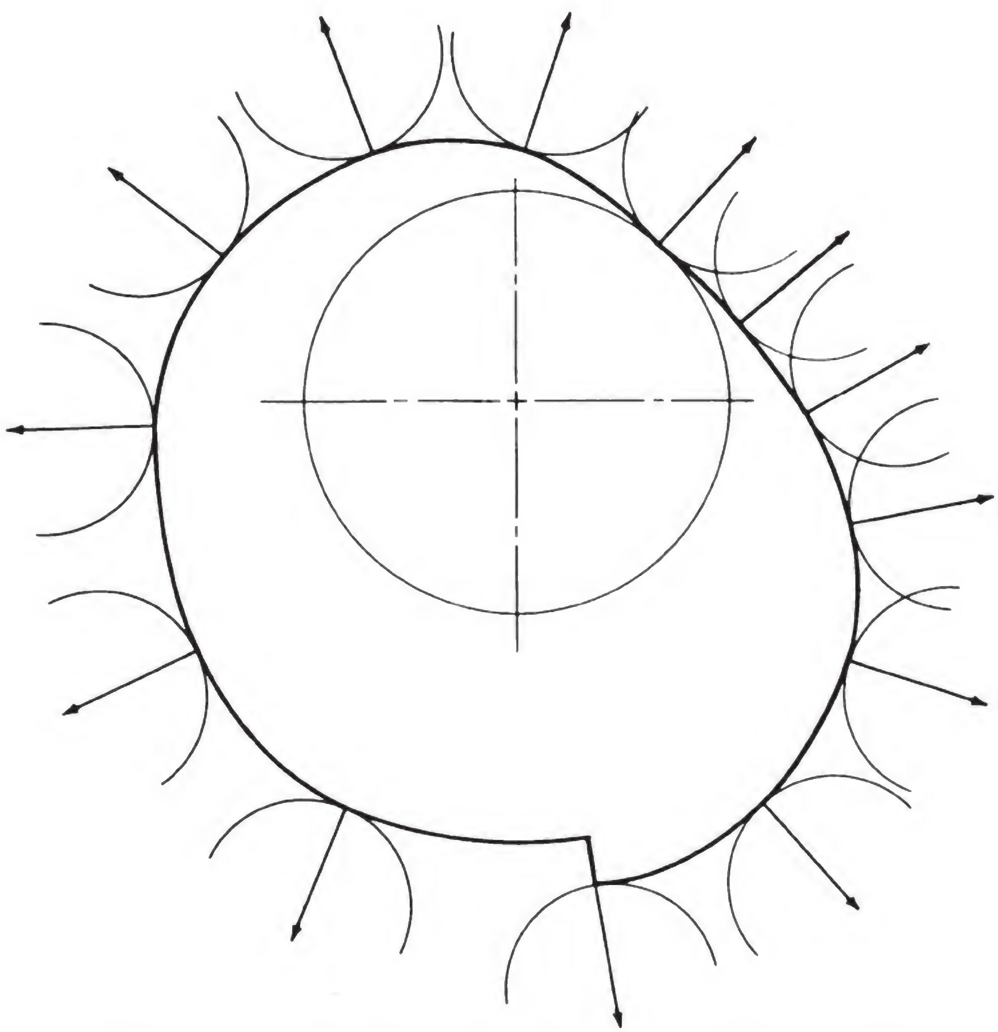


Figure 5–10.—Pressure lines of the roller follower against the contour of the cam.

JIGS AND FIXTURES

Jigs and fixtures are devices which are used to hold the work to be produced on a machine tool or to guide the drills or other tools so that duplicate parts will be interchangeable within designated tolerances. Usually, a device that is fastened to the machine and holds the work is called a fixture, while a jig is not fastened to the machine but is fastened to the work and guides the tools. However, some so-called drill jigs may also be fastened to the machine.

When a finished drawing of a jig or fixture is made, at least one view of the work is included to show how it fits in the jig or fixture. This view is usually drawn with a phantom line—a thin line with one long dash and two short dashes.

It is not likely that you will be required to make drawings of jigs or fixtures, since these pieces are rarely designed to be made except in factory production where a great number of parts are to be produced. In case it is required that you make such a drawing, make an effort to obtain a file copy of a drawing of a jig or fixture and study any existing jigs and fixtures at the activity where you work before you start your drawing.

GEARS

Aboard ships and at naval shore facilities, gears have always been highly essential elements of machinery. In the modern Navy, the emphasis on speed, power, and compactness in naval machinery has created special problems for the gear designer. Twelve types of commonly used gears are shown in figure 5–11. The four types which are ordinarily cut in machine shops are spur gears, bevel gears, helical gears, and worm gears.

To better understand gears, first consider the action of smooth-faced cylinders or wheels in rolling contact. Figure 5–12 shows two cylinders, one with a diameter of 4 inches and the other with an 8-inch diameter. If a point is marked near the edge of each of the cylinders and the

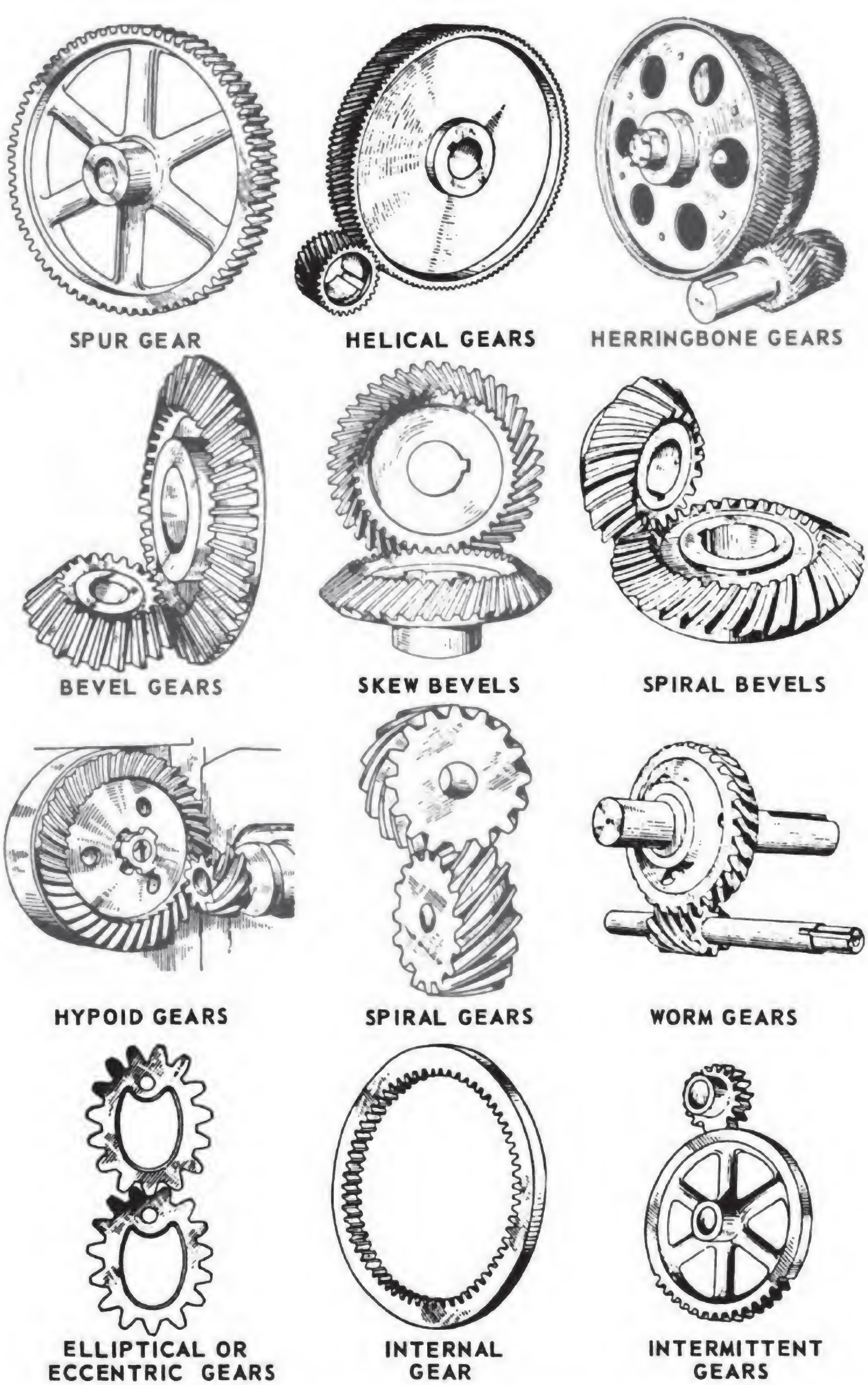


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Figure 5-11.—Twelve common types of gears.

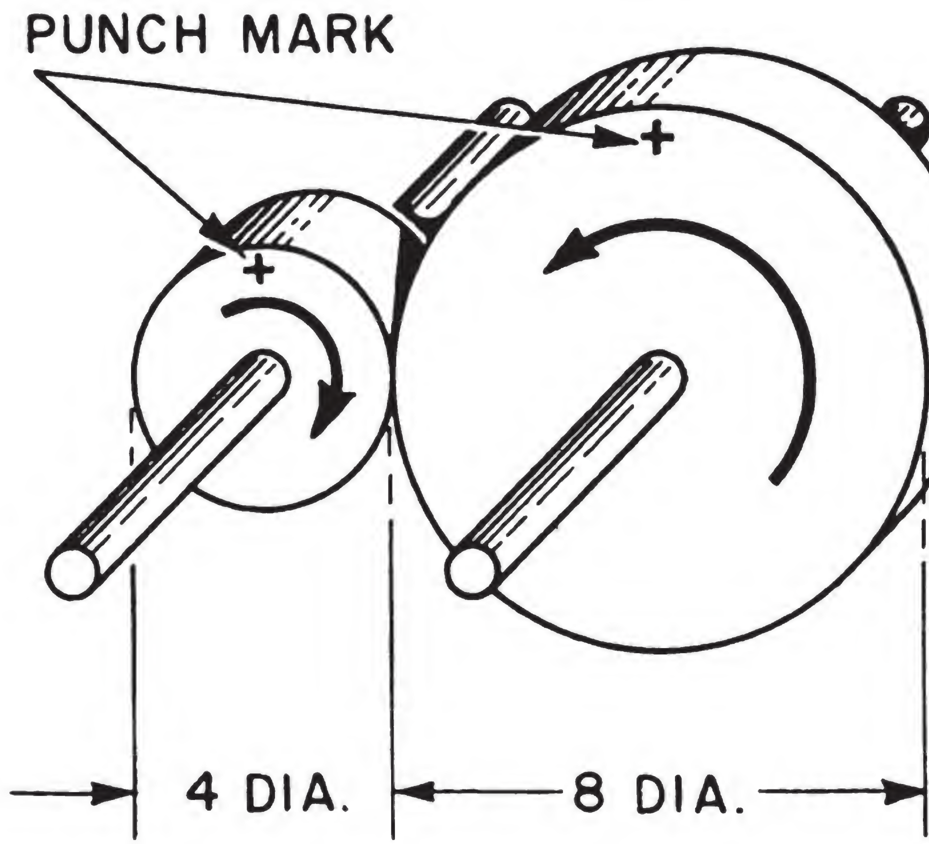


Figure 5–12.—Movement of two cylinders in rolling contact.

cylinders are rotated, one mark will have moved an inch when the other has moved an inch. If the smaller wheel makes $\frac{1}{2}$ revolution, the mark on it moves $6\frac{1}{4}$ inches along the circumference. At the same time, the larger wheel moves $6\frac{1}{4}$ inches as well, but it makes only $\frac{1}{4}$ of a revolution. If the smaller wheel makes a complete revolution, the large wheel will make $\frac{1}{2}$ of a revolution. The smaller wheel must make two complete revolutions to one revolution for the larger. Thus the speed ratio (2:1) is the inverse ratio of the circumference (4π:8π), and it is also the inverse ratio of the diameters (4:8).

If there were 10 gear teeth on the wheels to each inch of diameter, the speed ratio would become the inverse ratio of the number of teeth (40:80). In order to form

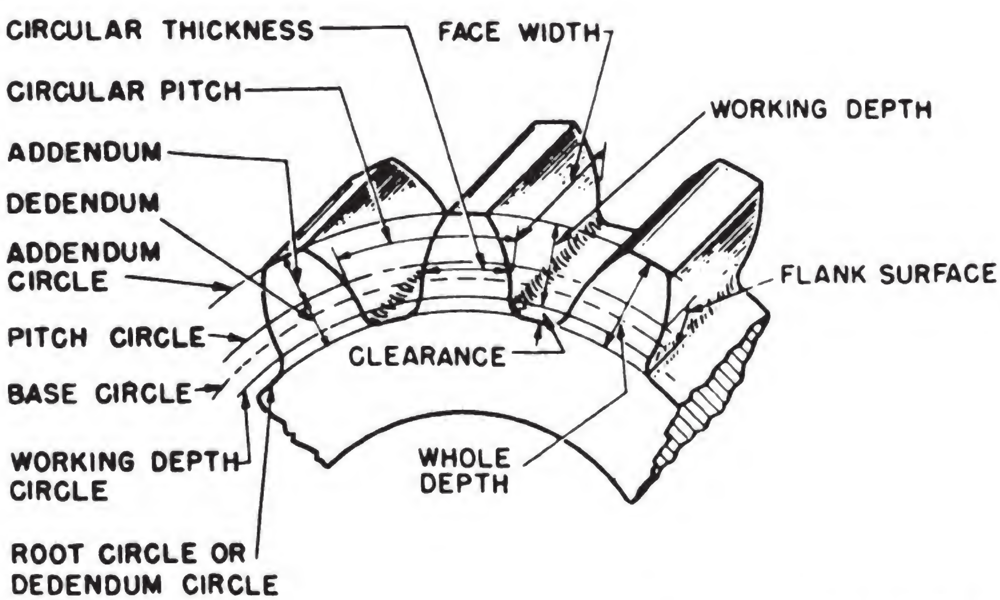
the teeth on these cylinders, the upper part of each tooth would have to be built up from the smooth face of the cylinder and material removed between the teeth to a slightly greater depth below the face of the cylinder. The 4-inch and 8-inch diameters would then exist only in theory. Nevertheless these imaginary circles play an important part in the design of the gears and are called the PITCH CIRCLES. Of course, in practice, gear teeth are never built up. The gear is turned out as a blank to the correct outside diameter, and metal is removed to the whole depth of the teeth.

Gear Nomenclature

Other terms used in describing gear teeth are illustrated in figure 5–13.

PITCH DIAMETER (*PD*).—Diameter of the pitch circle (or line) which equals the number of teeth divided by the diametral pitch.

NUMBER OF TEETH (*N*).—The diametral pitch multiplied by the diameter of the pitch circle ($DP \times PD$).



Courtesy International Textbook Co.

Figure 5–13.—Gear tooth nomenclature.

DIAMETRAL PITCH (DP).—The number of teeth to each inch of the pitch diameter or the number of teeth divided by the pitch diameter. Diametral pitch is usually referred to simply as PITCH.

ADDENDUM CIRCLE (AC).—The circle over the tops of the teeth.

OUTSIDE DIAMETER (OD).—Diameter of the addendum circle.

CIRCULAR PITCH (CP).—Length of the arc of the pitch circle between the centers or corresponding points of adjacent teeth.

ADDENDUM (A).—The height of the tooth above the pitch circle or the radial distance between the pitch circle and the top of the tooth.

DEDENDUM (D).—The length of the portion of the tooth from the pitch circle to the base of the tooth.

CHORDAL PITCH.—The distance from center to center of teeth measured along a straight line or chord of the pitch circle.

ROOT DIAMETER (RD).—The diameter of the circle at the root of the teeth.

CLEARANCE (C).—The distance between the bottom of a tooth and the top of a mating tooth.

WHOLE DEPTH (WD).—The distance from the top of the tooth to the bottom, including the clearance.

FACE.—The working surface of the tooth above the pitch line.

THICKNESS.—The width of the tooth, taken as a chord of the pitch circle.

CIRCULAR PITCH is the distance in inches measured from the intersection of the face and flank of one tooth to the same point on the adjacent tooth. That is, it is equal to $\frac{PD}{N}$ or $\frac{\pi}{DP}$. On a rack, it is called linear pitch.

PITCH CIRCLE.—The circle having the pitch diameter.

WORKING DEPTH.—The greatest depth to which a tooth of one gear extends into the tooth space of another gear.

Before the days of form cutters, indexing devices, and gear-cutting machines, most gears were cast from patterns and then filed more or less into shape. Circular pitch was then used to designate the size of the gear teeth, and easily measured pitches, such as $\frac{1}{4}$ inch, $\frac{1}{2}$ inch, $\frac{3}{4}$ inch, were used. When making a pattern, the patternmaker used the circular pitch or the chordal pitch to space the teeth in the gear.

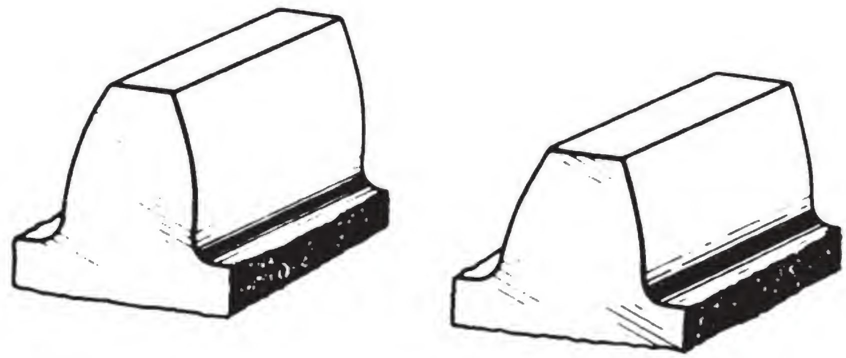
Today, circular pitch is used only in calculations for gears of coarse pitch, because for smaller pitches, a simpler and better system has been devised. This is the diametral pitch system, which is based on the diameter of the pitch circle, rather than on the circumference. With this system, indexing devices may be set to accurately space the teeth and therefore there is seldom any need to calculate circular pitch or chordal pitch. Mating gears must always have the same diametral pitch.

Spur Gears

Spur gears may be distinguished by the fact that the teeth are cut squarely across the outer rim of the gear blank in a direction parallel to the gear shaft axis. (See fig. 5–11.) On a standard involute spur gear, the tooth of one gear bears against the tooth of the mating gear at an angle of $14\frac{1}{2}$ degrees. This is called the pressure angle. Another spur gear tooth is the 20° stub tooth. It is much like the standard $14\frac{1}{2}°$ tooth, except that it has a pressure angle of 20° and a shorter tooth. (See fig. 5–14.)

The working depth of a spur gear tooth is equal to 2 divided by the pitch. That is, 12-pitch teeth are $\frac{2}{12}$ inch deep and 8-pitch teeth are $\frac{2}{8}$ inch deep. Remember that pitch means the number of teeth to each inch of the pitch diameter, or the number of teeth divided by the pitch diameter. Conversely, the pitch diameter is equal to the number of teeth divided by the pitch.

It is seldom necessary to draw an entire gear in detail, or even to draw any teeth at all. A conventional working drawing of a spur gear is shown in figure 5–15. To draw



A B

Figure 5–14.—A. A standard 14½° spur gear tooth. B. A 20° spur gear stub tooth.

a gear that has 24 teeth and 8 pitch, divide the 24 by 8 to get 3 inches, the pitch diameter. Draw the pitch circle with this diameter. (See fig. 5–15.) Note that the pitch circle is usually indicated by a broken line with long and short dashes alternating. Since the working depth will be equal to 2 divided by the pitch 8, or $\frac{2}{8}$, the outside circle should be drawn with $\frac{1}{8}$ of an inch greater radius

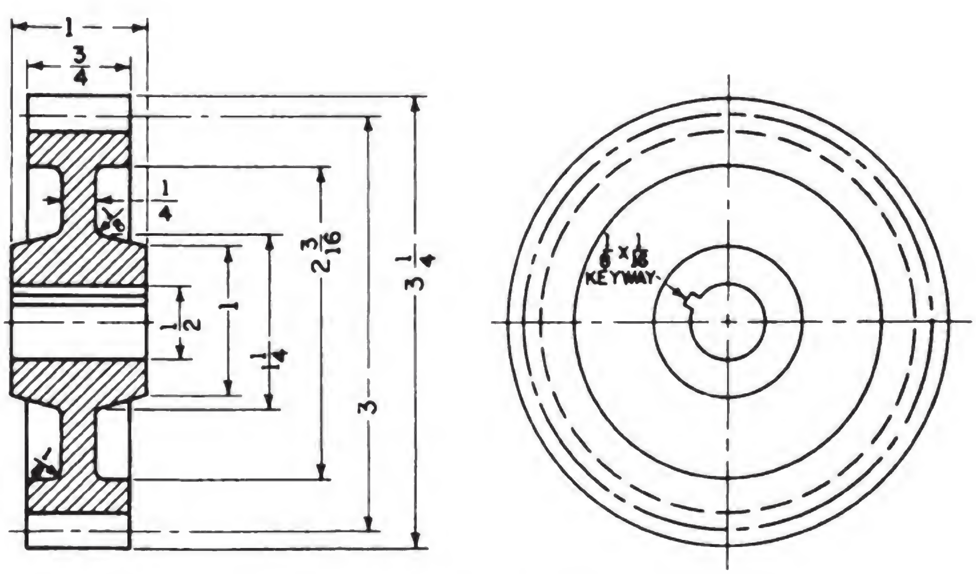


Figure 5–15.—Working drawing of a spur gear.

than the pitch circle, and its diameter will be $3\frac{3}{8}$ inches. The root circle should be drawn with $\frac{1}{8}$ of an inch smaller radius than the pitch circle, or $2\frac{6}{8}$ inches in diameter, except when allowance is also made for clearance.

The clearance can be found by dividing a constant by the pitch. For standard involute teeth, the constant used is 0.157. Clearance is provided in the shape of the formed cutter. It is not always necessary, however, to calculate the clearance for the purpose of drawing a root circle.

Once the calculations are made, the layout of a spur gear is relatively simply. Although it is seldom necessary for the draftsman to draw gears in detail, he should know how to draw at least one form of gear with the teeth. For this reason, instructions on drawing an involute tooth form on a wheel and rack are included here. The diameter of the pitch circle (*PD*) on the wheel is given as 12 inches and the number of teeth (*N*) as 36.

1. Calculate the values in inches, to three decimal places when necessary, for each of the following dimensions:

$$DP \text{ (pitch)} = \frac{N}{PD}.$$

$$WD \text{ (working depth of teeth)} = \frac{2}{DP}.$$

$$A \text{ (addendum)} = \frac{WD}{2}.$$

$$OD \text{ (outside diameter)} = PD + 2A.$$

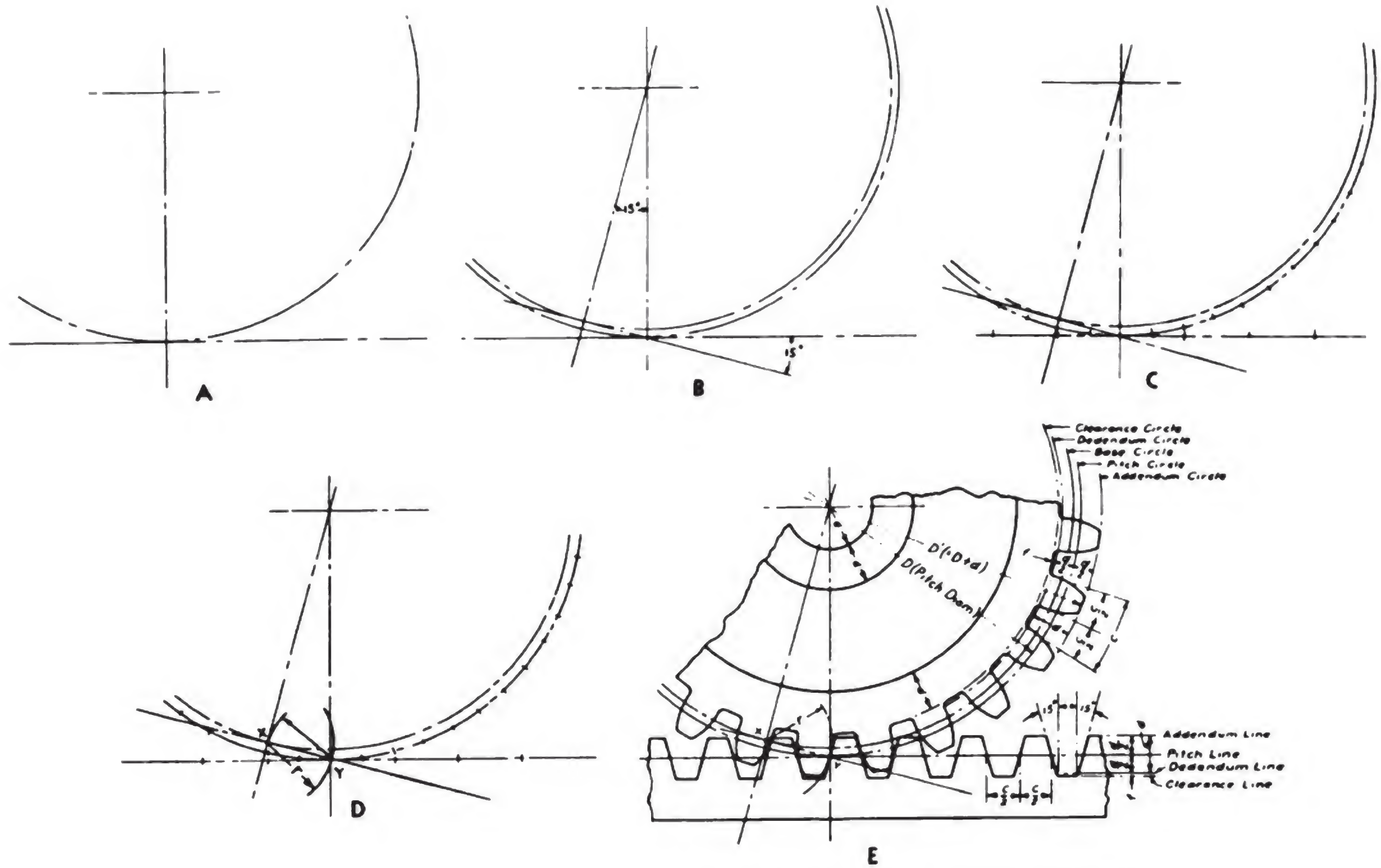
$$D \text{ (dedendum)} = A = \frac{WD}{2}.$$

$$RD \text{ (root diameter)} = PD - 2D.$$

$$CP \text{ (circular pitch)} = \frac{3.1416}{DP}.$$

$$T \text{ (thickness of teeth)} = \frac{CP}{2}.$$

2. Locate the center of the wheel and draw the pitch circles with a radius of $\frac{1}{2}$ the pitch diameter. Draw the



Courtesy Columbia Technical Institute.

Figure 5–16.—Approximate method of drawing teeth on a wheel and rack.

center lines of the wheel, and at the point where the vertical centerline intersects the bottom of the pitch circle, draw a horizontal line to represent the pitch line of the rack. (See fig. 5–16A.)

3. In order to draw the teeth by the approximate method given here, a circle called the BASE CIRCLE, which falls between the pitch circle and the root circle, must be drawn. In order to locate this circle, draw a line inclined at an angle of 15° through the intersection of the vertical center line and the pitch circle, and a second line from the center of the wheel inclined at an angle of 15° to the vertical centerline. (See fig. 5–16B). The distance from the intersection of these two lines and the center of the wheel is the radius for drawing the base circle. Fifteen degrees was selected because it is a convenient angle to draw and closely approximates the 14½° pressure angle of the teeth.

4. Set the small dividers at a distance equal to the thickness of the teeth and lay off the teeth on the pitch circle and then on the pitch line of the rack. The sides of the teeth in the rack are drawn at an angle of 15° with the vertical, as shown in figure 5–16E. The sides of the teeth in the wheel are drawn with a radius r as indicated in figure 5–16D.

5. With a center on the baseline, draw an arc with a radius of x to y through one of the points laid off with the dividers and repeat the procedure for all other points. In order to determine where the center should fall on the base circle, first draw an arc cutting the base circle with a center on one of the points on the pitch circle. Both sides of the teeth may be drawn by this method. (See fig. 5–16D.)

6. In completing the teeth of the wheel, draw fillets with a radius of $\frac{1}{16}$ inch connecting the sides of the teeth with the clearance circle. There are no fillets in the rack shown in this drawing. (See fig. 5–16D.)

RACK TEETH.—A rack may be compared to a spur gear that has been straightened out. The linear pitch of the

rack teeth must equal the circular pitch of the mating gear. The depth of the tooth is calculated in the same manner as the depth of a spur gear tooth.

INTERNAL SPUR GEARS.—Internal gears may be considered as circular metal bands with teeth on their inside surfaces. (See fig. 5–11.) These gears are proportioned like a standard spur gear turned outside in, or with dedendum and addendum in reverse positions. The rules for finding the dimensions of an internal spur gear, therefore, are similar in most cases to those for external gears.

STUB TOOTH GEARS.—Stub involute tooth gears are largely used in automotive drives because of their strength. This type of gear tooth has a 20° pressure angle and is short and thick. (See fig. 5–14.) Three systems of stub tooth gearing are in general use. These are the Nuttall, the Fellows, and the American Standards Association.

Bevel Gears

Bevel gears have teeth cut on an angular face for transmitting motion between shafts that are set at an angle to each other but are in the same plane. (See fig. 5–11.) When gears have their shafts at right angles, they are usually referred to as miter gears.

In addition to the gear nomenclature already given, you should know a few more terms which apply only to bevel gears. The names of the parts of a bevel gear are given in figure 5–17.

Laying out a bevel gear is more complicated than laying out a spur gear. A full section of a gear, fully dimensioned will usually serve as a working drawing. The gears shown in figure 5–18 are typical. The pitch is 8. One gear has 32 teeth, and the mating gear has 16. The shaft intersection is at 90 degrees.

First, draw the centerlines intersecting at 90° at the center point O, as shown in figure 5–18. Then locate the

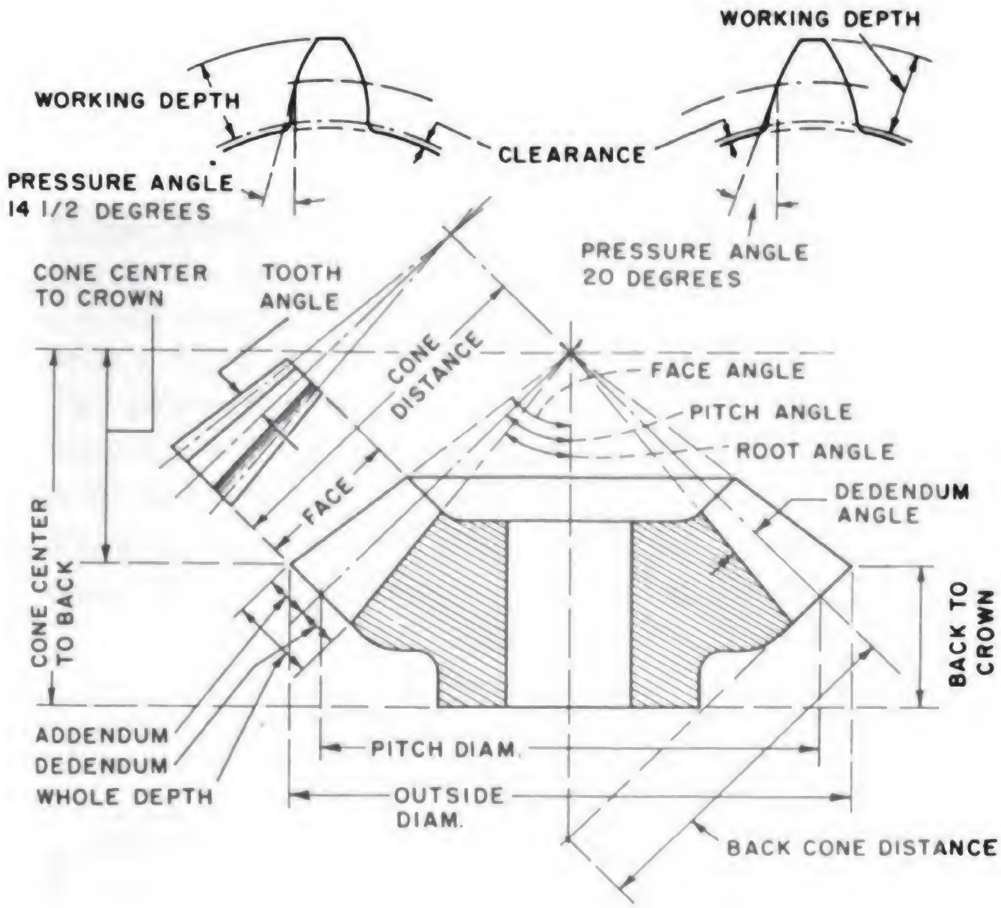


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Figure 5–17.—Parts of a bevel gear.

pitch lines. Since the pitch is 8 and there are 32 teeth in the larger gear, the pitch diameter will be $^{32}/_{8}$ or 4 inches. Draw lines parallel to the centerline for the gear and 2 inches on each side of it to define the limits of the pitch line, as shown in figure 5–18A. Locate the pitch line of the smaller gear in the same manner. Since there are 16 teeth in this gear, the pitch line, or pitch diameter will be $^{16}/_{8}$ or 2 inches, extending 1 inch on each side of the centerline.

Then draw lines through the end points of the pitch lines to the center O. These lines are the pitch cones and

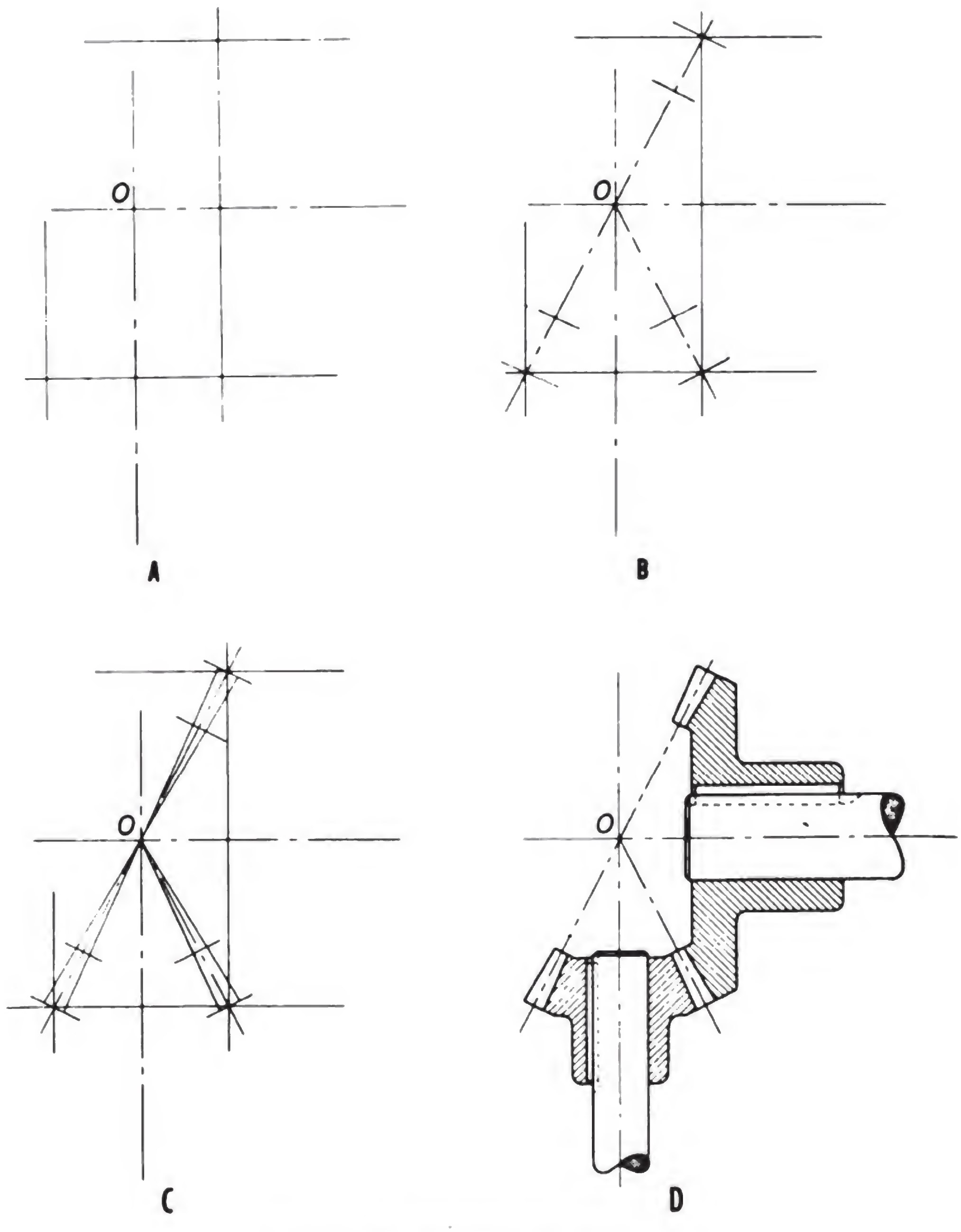

Figure 5–18.—Drawing of a bevel gear.

O is the cone vertex. (See fig. 5–18B.) Perpendicular to the pitch cone elements, draw the lines that form the material conical surfaces of the gear teeth. On these lines, lay off the addendum and dedendum of the gear teeth. Since the teeth are 8 pitch, each of these will be 1/8

of an inch from the pitch line. (See fig. 5–18C.) Note that the addendum of one gear is the dedendum of the other and vice versa. No allowance for clearance has been made on this drawing. If clearance is to be allowed for, two other lines must be drawn slightly further from the pitch line.

Draw lines from these points to the cone center *O*, forming the faces and bottoms of the teeth. Then draw the lines defining the width of the gear face. (See fig. 5–18D.) Note that the width of the gear face is made 1/3 the pitch cone radius for gears up to 3 inches in pitch diameter, and 1/4 the pitch cone radius for gears with 3 to 20 inches of pitch diameter.

Finally, complete the drawing of the gears, including section lining and dimensioning. (See fig. 5–18D.)

Other Types of Gears

Worm gearing is used when a large reduction in velocity is desired or when considerable increase in mechanical advantage is required or both. As shown in figure 5–11, a worm gear set combines a screw or worm with a worm wheel which has helical teeth and is mounted on a shaft usually at right angles to that of the worm.

Helical gears, often incorrectly referred to as spiral or skew gears, have teeth cut across the outer rim of the gear blank at an angle to their axis, so that they are similar to the thread of a screw. (See fig. 5–11.) Helical gears are commonly made with a tooth angle of 45°, since this angle provides a very efficient and durable gear, although any angle which permits the teeth to engage properly may be used.

Helical gears may be used to transmit power between shafts that are parallel or between shafts that are not parallel and not in the same plane. Their action is smoother and quieter than spur gears, but they develop more tooth friction and produce a certain amount of end thrust on the shaft.

For transmitting mechanical power for some distance, belts and pulleys are generally used. The belts may be made of leather, cotton, canvas, Balat (canvas impregnated with balata gum), rubber, or steel. Belts may also vary in shape. They may be flat, round, or trapezoidal as in the case of the V-type belt, which is very commonly used in the Navy. Ropes and chains may also be used on pulleys. Flat belts may be used not only for transmission of power but also for conveying material.

Pulleys are also made in various designs and arrangements. Pulleys which carry V-type belts are grooved. For lower speeds, flat belts and crowned face pulleys are used. (See fig. 5–19.) The face of a pulley is crowned to keep the belt from slipping off. When the belt is riding on one side of the pulley, the rise of the crown on the face of the pulley stretches one edge of the belt and causes it to pull the belt up the crown until the belt rides on the centerline and the pull on both edges is equal.

Crowned flange pulleys are usually used where high speeds are required, to prevent the slipping of the belt. The step cone pulley is used when it is necessary to provide a range of speed variation in a shaft which is belted to a line shaft running at a constant speed. The important thing about step pulleys is that the diameters of the steps must be so proportioned that the length of the belt remains constant when it is shifted from one step to another. In order to maintain this condition, the sum of the diameters (pitch diameter for V-belt pulleys) of each pair of steps must be constant. In figure 5–20, a three-step cone is shown with a crossed belt. Adding the diameter, you will find that 17 is the constant for this cone pulley.

Idler pulleys are used as belt tightening devices, belt guides, and belt conveyors. Their faces are flat rather than crowned. There are also idlers on V-belts, and they are used when V-belts are used as clutches. When the idler is used on a V-belt as a tightener, it should be used

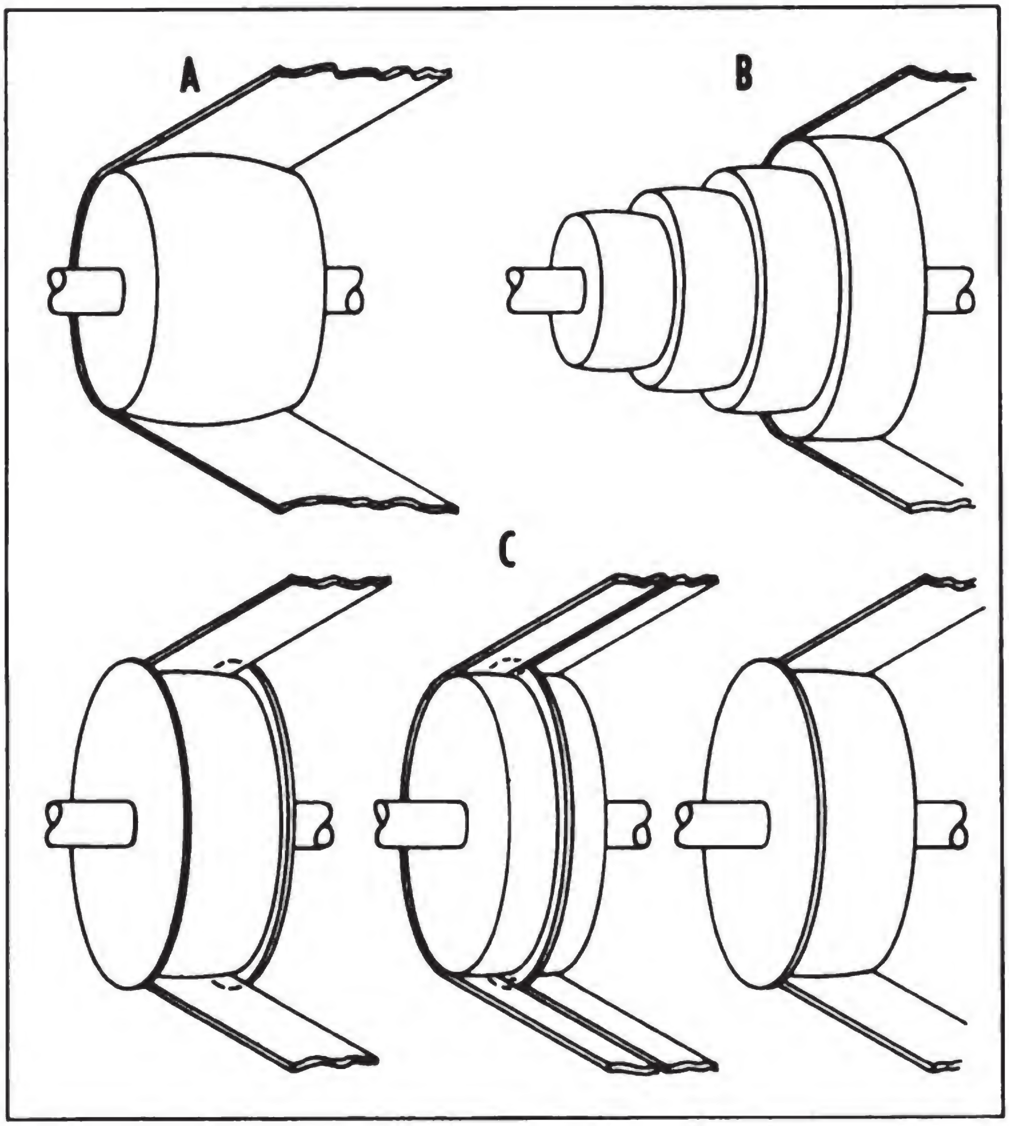

Figure 5–19.—A. Crowned face pulley. B. Step cone pulley. C. Crowned flange pulleys.

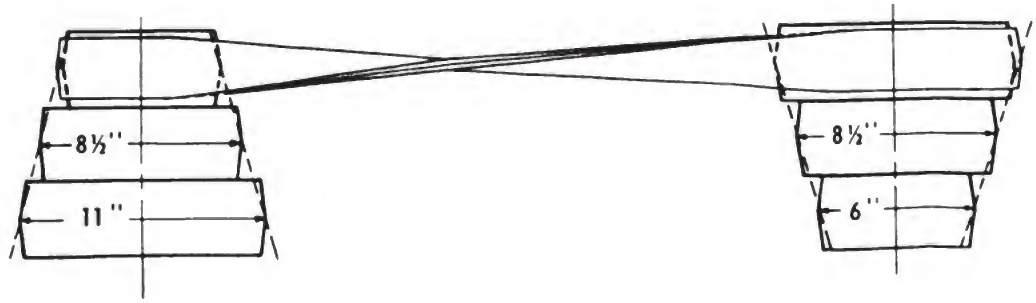

Figure 5–20.—Three-step cone with a crossed belt.

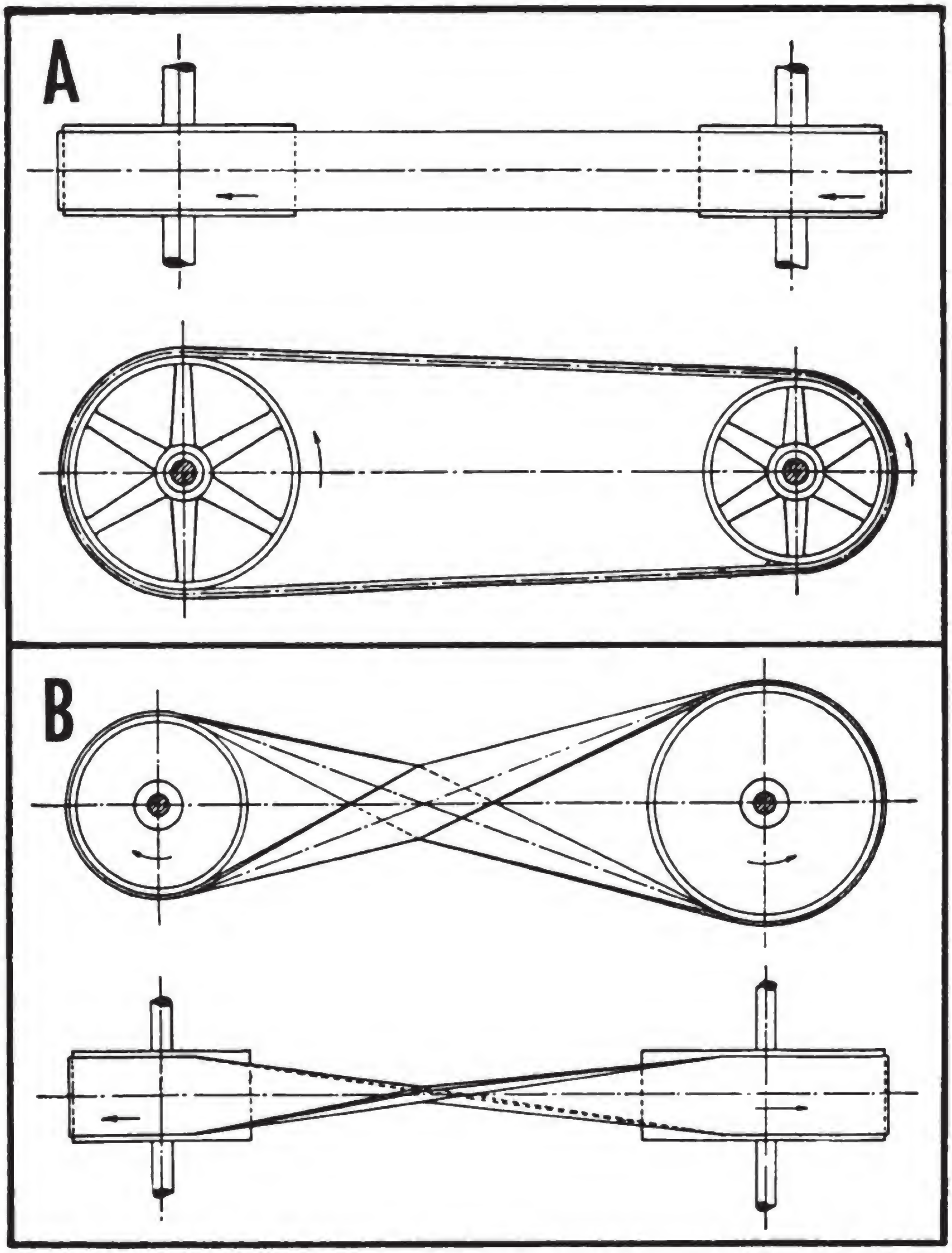

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Figure 5–21.—A. Diagram of a simple open belt drive. B. Diagram of a simple crossed belt drive.

on the inside, rather than the outside. Used on the outside, it gives a reverse flex, which is bad.

There are various types of drives. The driving and the driven pulleys may be on parallel shafts and the belt run directly from one to the other, as shown in figure 5–21A, or the belt may be crossed, as shown in figure 5–21B.

Sometimes the shafts of the driving and driven pulleys are not parallel. The deviation from the parallel position of the shafts may be as much as 90°, in which case the drive is called a quarter-twist belt drive. Such a drive is not reversible when using flat belts unless guide pulleys are used.

TAKEOFFS AND PARTS LISTS

A parts list, like the bill of materials on construction drawings, may be required on a machine drawing. Such a list is usually placed on an assembly drawing and gives the name, quantity, material, stock size or weight, stock number, or drawing number of each part. A column may be added for remarks. Usually the larger or more important parts are listed first and the smaller or standard parts, such as screws, last.

When you make such a list, it is very important that you include every part. It is best to work out a system for taking the parts from the drawing and then later arrange the parts in order for the parts list. It is always wise to have your takeoff checked by someone else, since another man is less likely to make the same mistakes.

QUIZ

1. Why should layouts be made to as large a scale as possible?
2. Why does a cam designed to move with uniform motion require a powerful mechanism to move it and why is it used only to move light objects?
3. What type of motion is shown by the sine curve?
4. What curve is the curve of constantly accelerated and retarded motion similar to mathematically?
5. (a) What is a jig? (b) What is a fixture?
6. What is the distinguishing characteristic of spur gears?
7. What is the working depth of a spur gear tooth?
8. Describe bevel gears.
9. When two bevel gears have their shafts at right angles, what may they be called?
10. When is worm gearing used?
11. How are the teeth of helical gears cut?
12. For what purposes are belts and pulleys used?
13. Why must the sum of the pitch diameters of each pair of steps be constant for step cone pulleys?
14. How are idler pulleys used?
15. When may a quarter-twist flat belt drive be reversible?
16. What type of information should be given in a parts list?

CHAPTER 6

MECHANICAL DRAFTING

INTRODUCTION

Mechanical drafting includes layouts and details for systems of plumbing, heating, ventilating, air conditioning, and refrigeration. These systems may vary, depending on whether they are aboard ship or shore based. Ashore they may be permanent installations with the most modern fixtures, equipment, and appurtenances, or they may be temporary installations at advanced bases, in which the cheapest materials which will serve the purpose are utilized. In this chapter, only a few of the basic systems will be discussed. It is felt that the individual draftsman, once he understands the principles involved in the basic systems, will be able to follow the variations involved in more specialized systems.

The Bureau of Yards and Docks has published in NavDocks TP–Te–4, *Basic Mechanical Engineering* and NavDocks TP–Pw–30, *Maintenance and Operation,* the criteria to be followed in the design, installation, maintenance, and operation of plumbing, heating, ventilating, air-conditioning, refrigerating, and dehumidifying systems. You may find it of value to obtain a copy of these publications for reference purposes. However, you are not expected to design such systems. It will be your job to work from design drawings or sketches made by engi-

neers or engineer officers to make layouts of such systems and detail drawings of portions of them. The requirements for mechanical layouts are given in NavDocks TP–Te–1, *Surveys, Drawings and Specifications.*

For a more complete discussion of materials and methods used in the plumbing trade, read MC 760, *How to Design and Install Plumbing.* For a wider discussion of air-conditioning, heating, and ventilating, read MB 761, *Air-Conditioning, Heating, and Ventilating.* These are available as texts for the USAFI courses MC 760 or CC 760, Plumbing, and MB 761 or CB 761, Air-Conditioning, Heating, and Ventilating.

The Bureau of Yards and Docks has also published a number of technical publications—NavDocks TP–Pw–15, *Sewerage Systems;* NavDocks TP–PL–6, *Water Supply for Advanced Bases;* NavDocks TP–Pw–12, *Water Supply Systems;* NavDocks TP–Pw–1, *Storm Drainage Systems;* and NavDocks TP–Pu–4, *Fire Prevention and Fire Protection*—which may be of value to you. The publication of the U.S. Department of Commerce, *Report of the Coordinating Committee for a National Plumbing Code,* contains the standard practices and requirements for plumbing systems.

For conditions found in heating, ventilating, and air-conditioning systems, which are not covered in TP–Te–4, reference is made to the annual American Society of Heating and Air-Conditioning Engineers (ASHAE) *Guide.* All direct heating apparatus, and all air ducts and ventilating equipment, especially in hazardous locations such as paint shops, galleys, and kitchens, should conform to the standards of the National Board of Fire Underwriters (NBFU). Fire dampers should comply with NBFU Pamphlet No. 90. Heating and boiler codes and standards are covered in chapter 6 of *Power Generation and Distribution,* NavDocks TP–Pu–3. Equipment for paint shops is discussed in *Fire Prevention and Fire Protection,* NavDocks TP–Pu–4. All details of central

steam heating plants are presented in chapter 6 of *Power Generation and Distribution,* NavDocks TP–Pu–3.

PLUMBING

Plumbing systems include water, sanitary and industrial waste, and vent, storm drainage, and gas and special piping systems in and adjacent to buildings, together with their fixtures and appurtenances. Special piping systems include those required for fire protection, nonpotable flushing, liquid or gas laboratory supply, and waste systems.

The rules and regulations that govern the design of a plumbing system have been standardized to assure good, economical layouts. The standard system includes water service pipes, building drains, and building storm drains, if required, from their connections in the building to points 5 feet outside. All pipes, fixtures, vents, branches, devices, rain leaders, and connected storm branches are parts of the system. Building sites in the field should be selected with full consideration given to the location of sewers, water mains, and other service systems because the requirements of these systems govern the direction of runs for the piping.

Drawings should show, in large scale, the details and dimensions of all congested areas so that all work relative to structural features of the building is located. Each set of drawings should have a legend giving the applicable symbols and abbreviations listed in current military standards of drawing practice, MIL–STD–17, *Mechanical Standards.* If practicable, all notes, legends, and schedules should be grouped to the right of the drawings above the title block, leaving sufficient space for an expanding revision block.

Kinds of Pipe

Pipe used for Navy plumbing systems inside buildings may be black steel, zinc-coated steel, wrought iron, zinc-coated wrought iron, brass, copper, or cast iron. The kind

of pipe and the size to be used for any specific installation is given in the specifications.

TP–Te–4, *Basic Mechanical Engineering,* lists the kinds of pipe and their uses. Commonly, water pipe is galvanized steel with screw threads or copper tubing with soldered joints. The diameters of pipe used depend on the number of fixtures served. Within the building and 5 feet outside of the outer walls, waste or soil pipe below ground is cast iron with bell and spigot ends and caulked joints. Within the building and above ground, waste and vent stacks are galvanized steel with screw threads.

All pipe sizes for pipe up to 12 inches in diameter, are nominal inside diameters. The true diameter may vary, depending on the thickness of the walls. Pipe comes in standard, extra strong, and double extra strong weights, depending on the wall thicknesses.

The joints on waste pipe below ground must be of the bell-and-spigot type so that the inside diameters of the two pipes to be joined will be the same. Waste pipes should be free from any projections on which solid matter might lodge. A bell-and-spigot joint is shown in figure 6–1. This joint has been filled with oakum and lead and caulked with irons to make it watertight.

The standards for pipe threads are given in *Screw-*

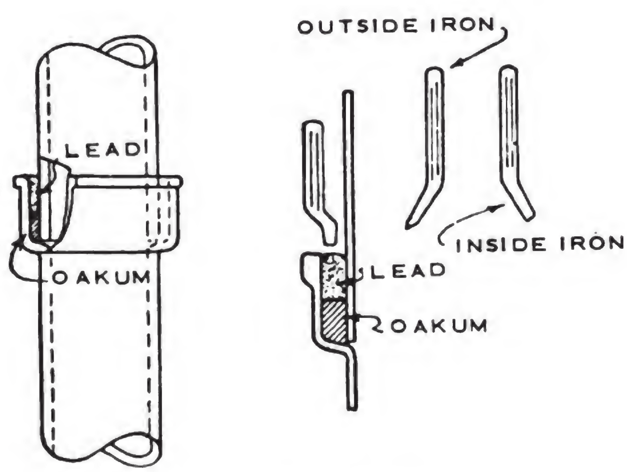


Figure 6–1.—Bell-and-spigot joint.

thread Standards for Federal Services 1944, Handbook H28, published by the National Bureau of Standards. The normal type of joint, made with American National pipe threads, is that employing an external taper and an internal taper thread, as shown in figure 6–2. The threads are cut with a taper of 1 in 16, or 0.75 inch per foot,

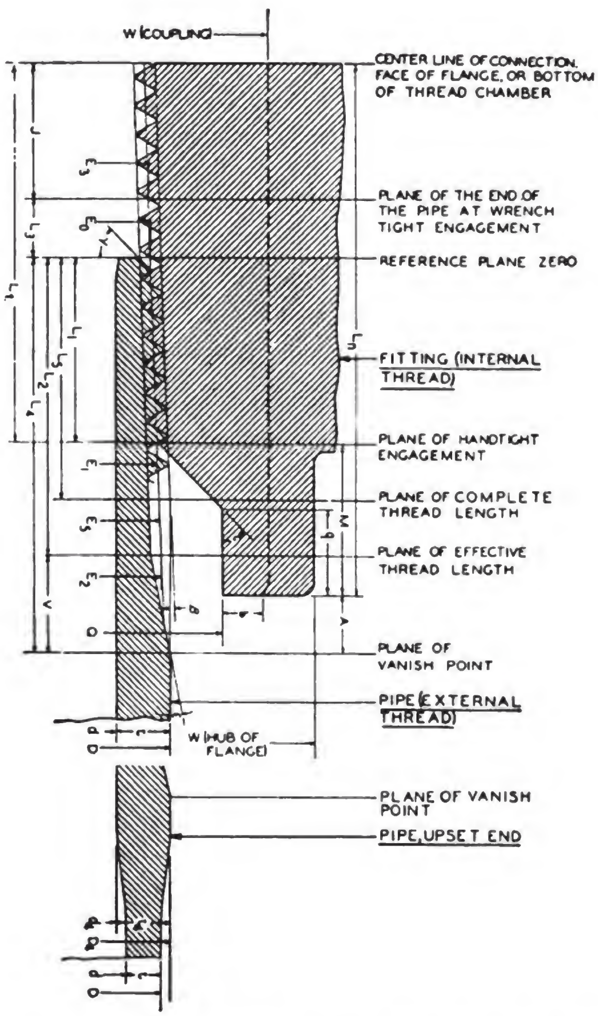


Figure 6–2.—American National taper pipe thread.

measured on the diameter and along the axis. This fixes the distance that a pipe enters a fitting and ensures a tight joint. Pipe threads are represented on drawings by the conventionalized symbols for screw threads.

Pipe Fittings

Standard water pipe fittings such as are used on steel and wrought iron pipe are shown in figure 6–3. They have a standard tapered thread, and are of galvanized cast iron or malleable iron.

Copper pipe is manufactured as a flexible tube and in a rigid form, which makes it very adaptable. The fittings are soldered, as shown in figure 6–4, and are of the same design as the malleable fittings in figure 6–3.

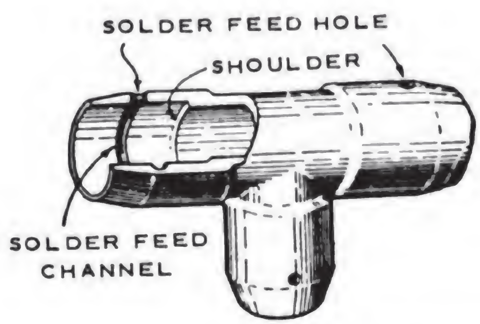
Fittings for cast iron waste pipe are shown in figure 6–5. Various types of bends are shown in A; elbows are shown in B; Y and tee branches in C; and special cast iron fittings in D. Bends are used in soil, waste, and drain lines to complete change of direction. Elbows are used at the base of soil and waste stacks. They are also used for change of direction on horizontal and vertical installations. The Y and tee branches are used for change of direction and branch connections of soil, waste, and drain pipes.

Fittings used on steel and wrought iron pipe are also cast iron, but they differ from those shown in figure 6–5, because they are the recessed variety which is tapped with a standard pipe thread. Figure 6–6 shows cast iron recessed drainage fittings. In making change of direction, fittings of a long radius or a combination of Y's and elbows of 45° should be used.

To prevent sewer gases from entering buildings by way of the pipes, traps are used. A trap serves to form a water seal which blocks the passage to the gases. The P-trap shown in figure 6–7A must be installed as close to the fixture as possible to overcome the tendency of the inlet side of the trap to become fouled. A common seal trap, providing a water seal of 2 inches, is shown in figure 6–7B. A deep seal trap, providing a water seal of 4 inches, is shown in figure 6–7C. Without proper ventilation in the system, even the deep seal pipe does not provide against seal loss. Since all traps are subject to obstruction because of their shape, they must be

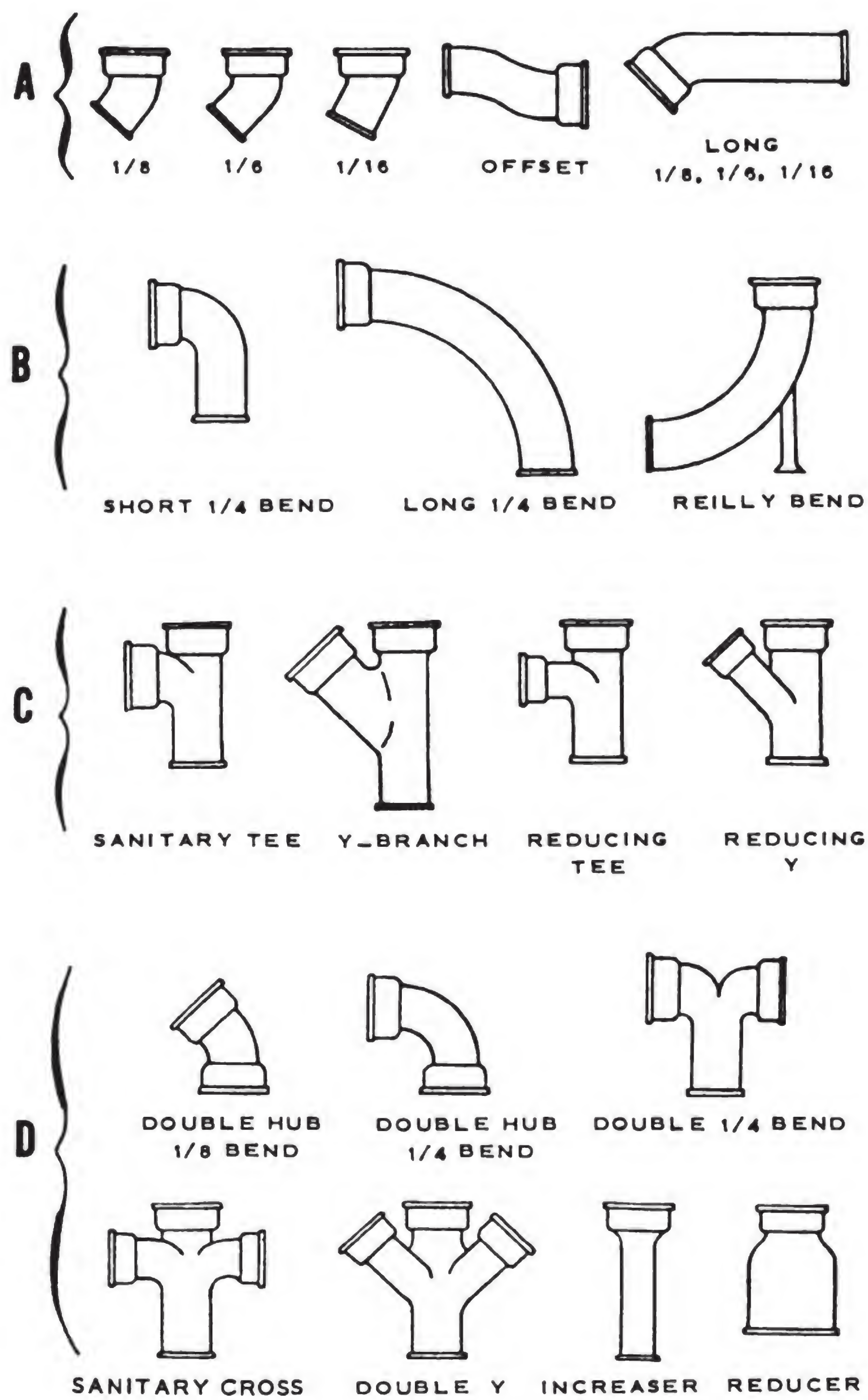
Courtesy of the American Technical Society.

Figure 6–3.—Standard water pipe fittings.



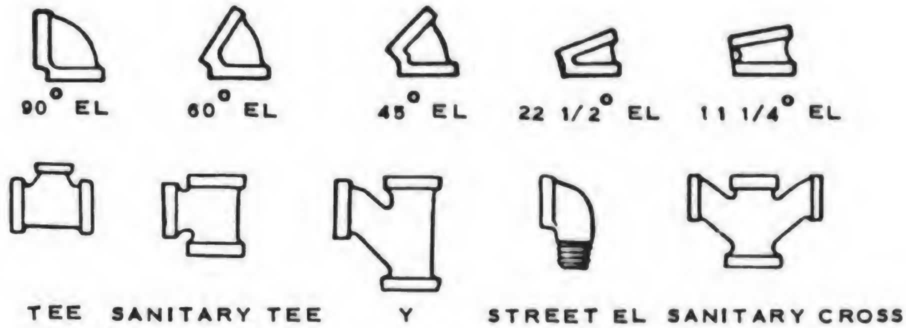
Courtesy of the American Technical Society.

Figure 6–4.—Soldered fitting.



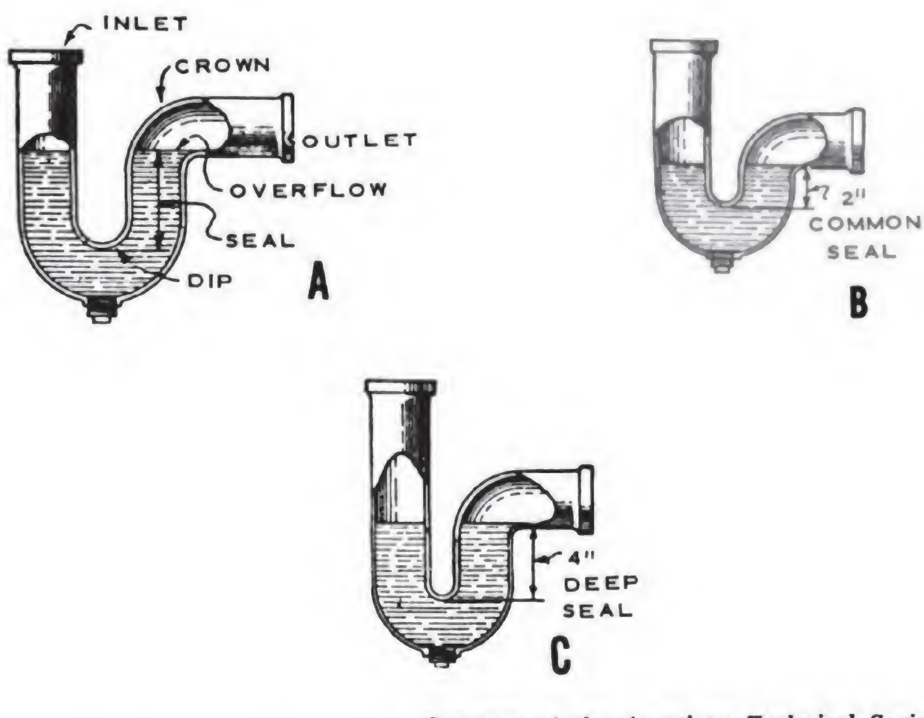
Courtesy of the American Technical Society.

Figure 6–5.—Fittings for cast-iron waste pipe.



Courtesy of the American Technical Society.

Figure 6–6.—Cast iron, recessed, drainage fittings.



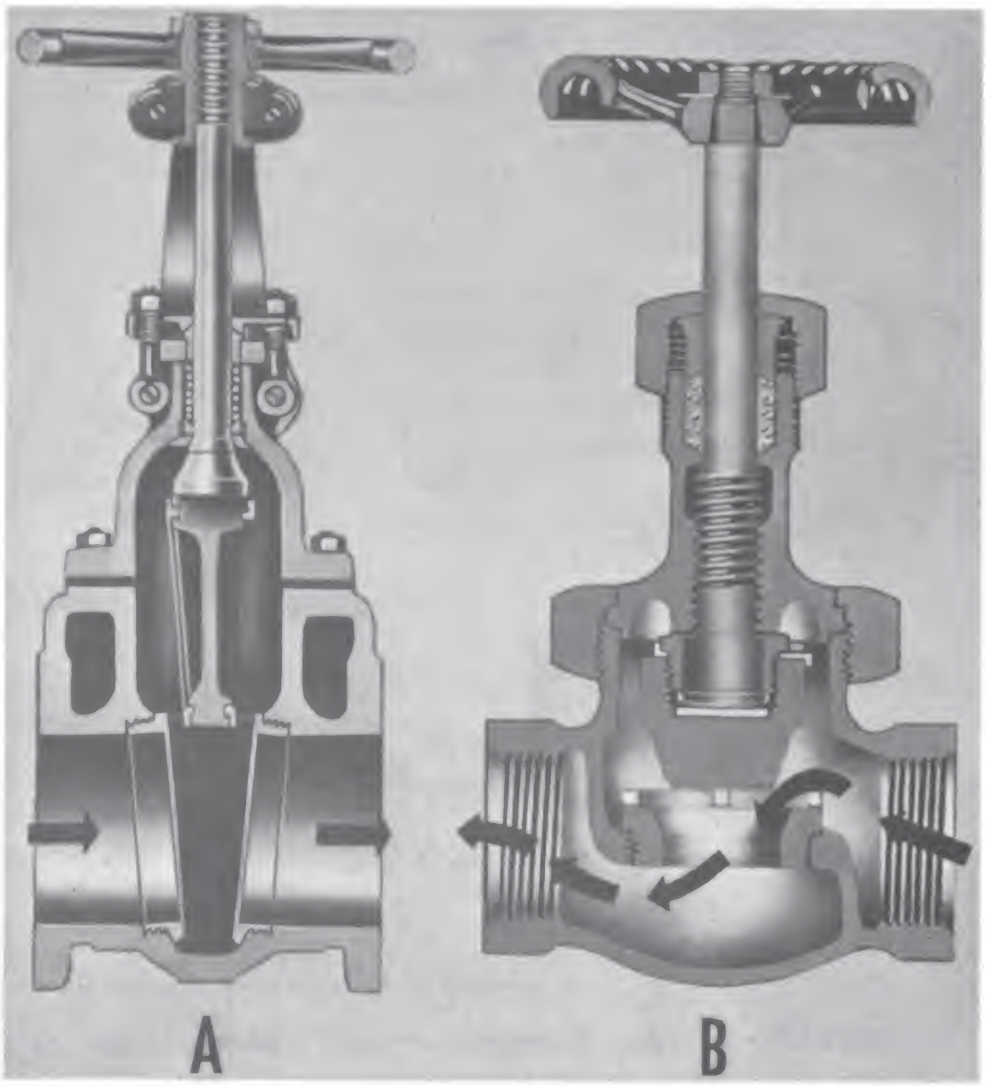
Courtesy of the American Technical Society.

Figure 6–7.—A. P-trap. B. Common seal trap. C. Deep seal trap.

provided with a cleanout or designed so that they can be easily disassembled.

Valves

There are many different types of valves used for different purposes in plumbing systems. Valves are installed to control a fixture or a group of fixtures so that the entire system will not become inoperative when work must be done at a specific location.



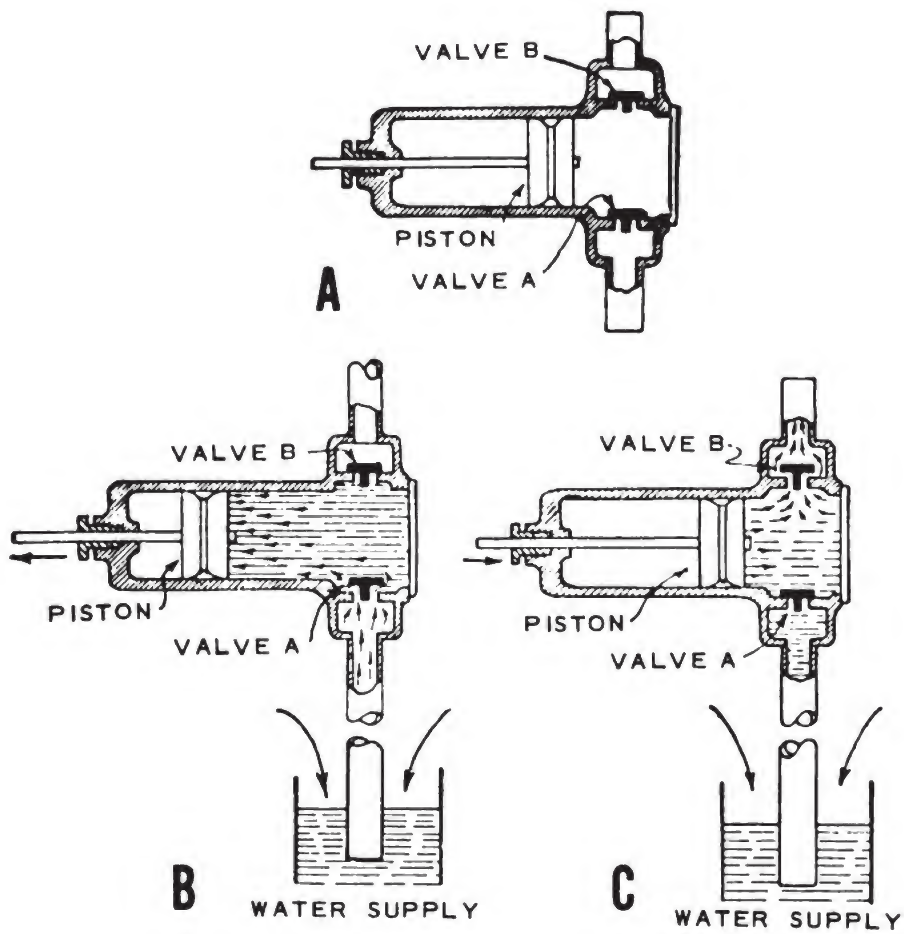
Courtesy of the American Technical Society.

Figure 6–8.—A. Gate valve. B. Globe valve.

Two common types of valves are shown in figure 6–8. The gate valve provides an unretarded flow when it is open. The gate is raised and lowered by means of a screw stem attached to a wheel handle. The globe valve in figure 6–8B is used where unretarded flow is not required and where the valve must be used consistently to control water.

Types of Pumps

Pumps are often used in plumbing systems since water pressure may be insufficient for the water to rise in the



Courtesy of the American Technical Society.

Figure 6–9.—Single-action pump. A. Piston in neutral position. B. Suction stroke. C. Delivery stroke.

pipes without them. The two kinds of pumps commonly used are the piston pump and the centrifugal pump. Whichever type of pump is used, the principle behind it is the same. A pump produces a vacuum within itself which permits it to lift water by atmospheric pressure. The old saying, "Nature abhors a vacuum," applies. A gas or a liquid will rush in to fill any vacuum.

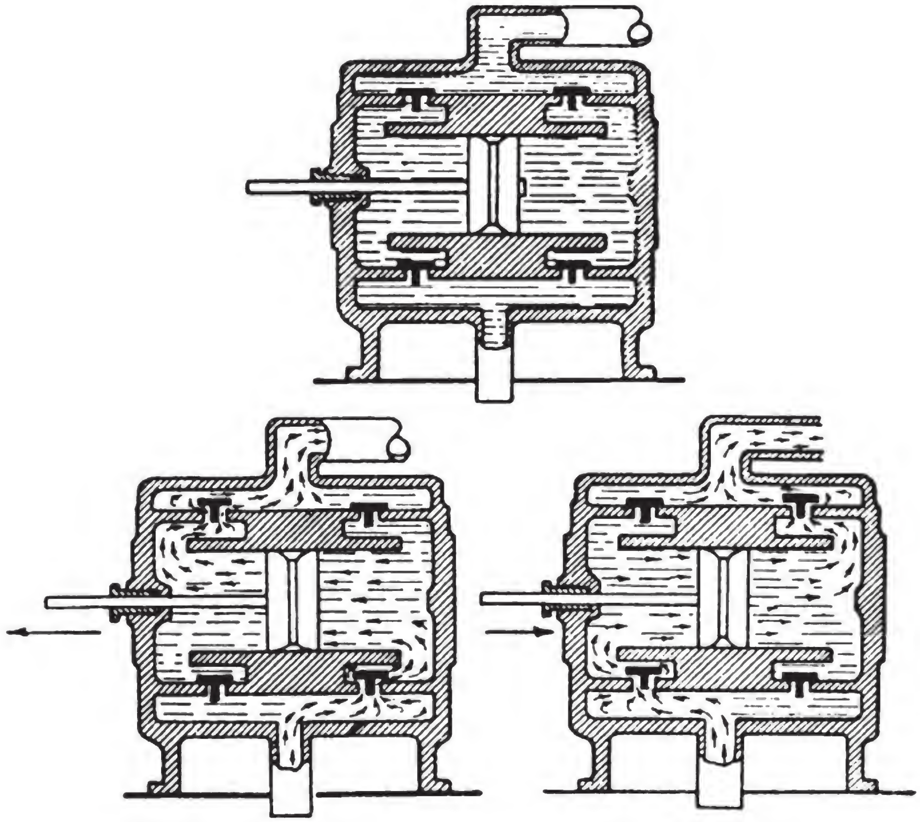
Piston pumps may be single-action, double-action, or duplex piston. A single-action pump is shown in figure 6–9. The pump consists of a cylinder, fitted with a piston and two one-way valves providing for inlet and outlet of the water. In figure 6–9B, the piston is drawn back, resulting in a vacuum into which water is drawn through the inlet valve. Since there is no pressure forcing the outlet valve up, it remains closed. In figure 6–9C, the piston is driven forward on the delivery stroke. The pressure of the water closes the inlet valves and opens the outlet valve.

A double-action pump operates in much the same way except that there are two chambers and four valves. On one stroke of the piston, water is delivered from one chamber. On the return stroke, it is delivered from the other. (See fig. 6–10.)

However, with a double-action pump there will still be a pulsating action in the delivery of the water. To eliminate this, an air chamber may be used, as shown in figure 6–11. The air in the chamber is compressed by the pressure of the water at the peak of a stroke, but expands as the piston approaches the neutral position. Acting like a cushion or spring, it keeps the water flowing evenly into the system.

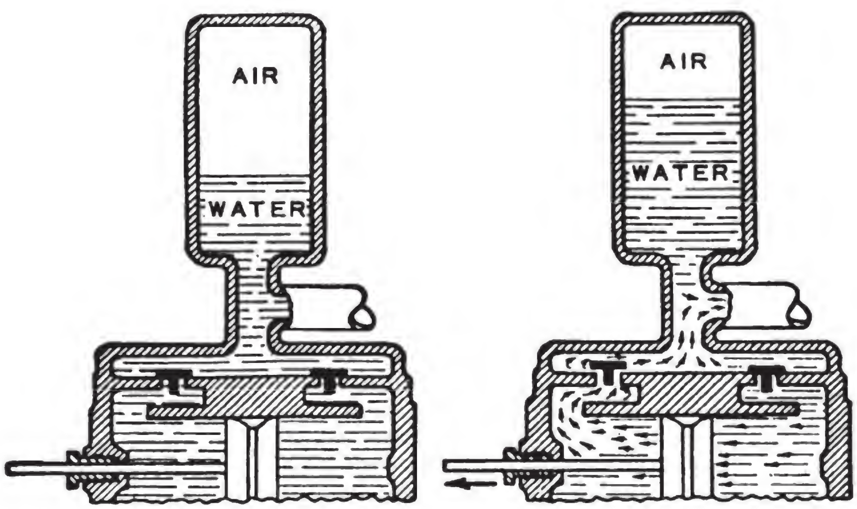
Duplex, or twin, piston pumps are constructed of twin cylinders with pistons operating in each to deliver water. These pumps may contain eight or more valves, instead of two or four.

The type of pump commonly used in modern buildings is the centrifugal pump. A centrifugal pump is built with



Courtesy of the American Technical Society.

Figure 6–10.—Double-action pump.



Courtesy of the American Technical Society.

Figure 6–11.—Air chamber for eliminating pulsating action of pump.

a housing of metal, the inside of which is an accurately machined chamber containing an impeller or water wheel. The more efficient impellers are built of a solid piece of metal containing a number of small pockets which pick up water on the inlet side of the pump and expel it on the outlet side. (See fig. 6–12.)

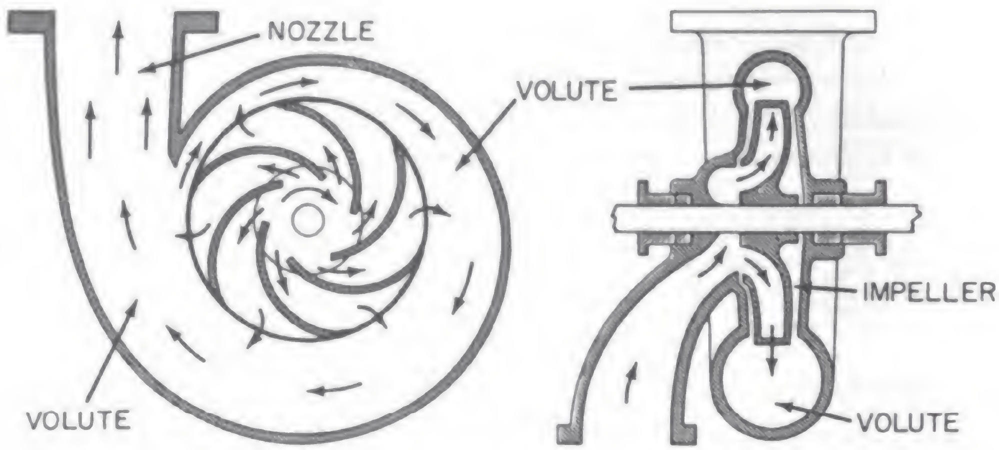
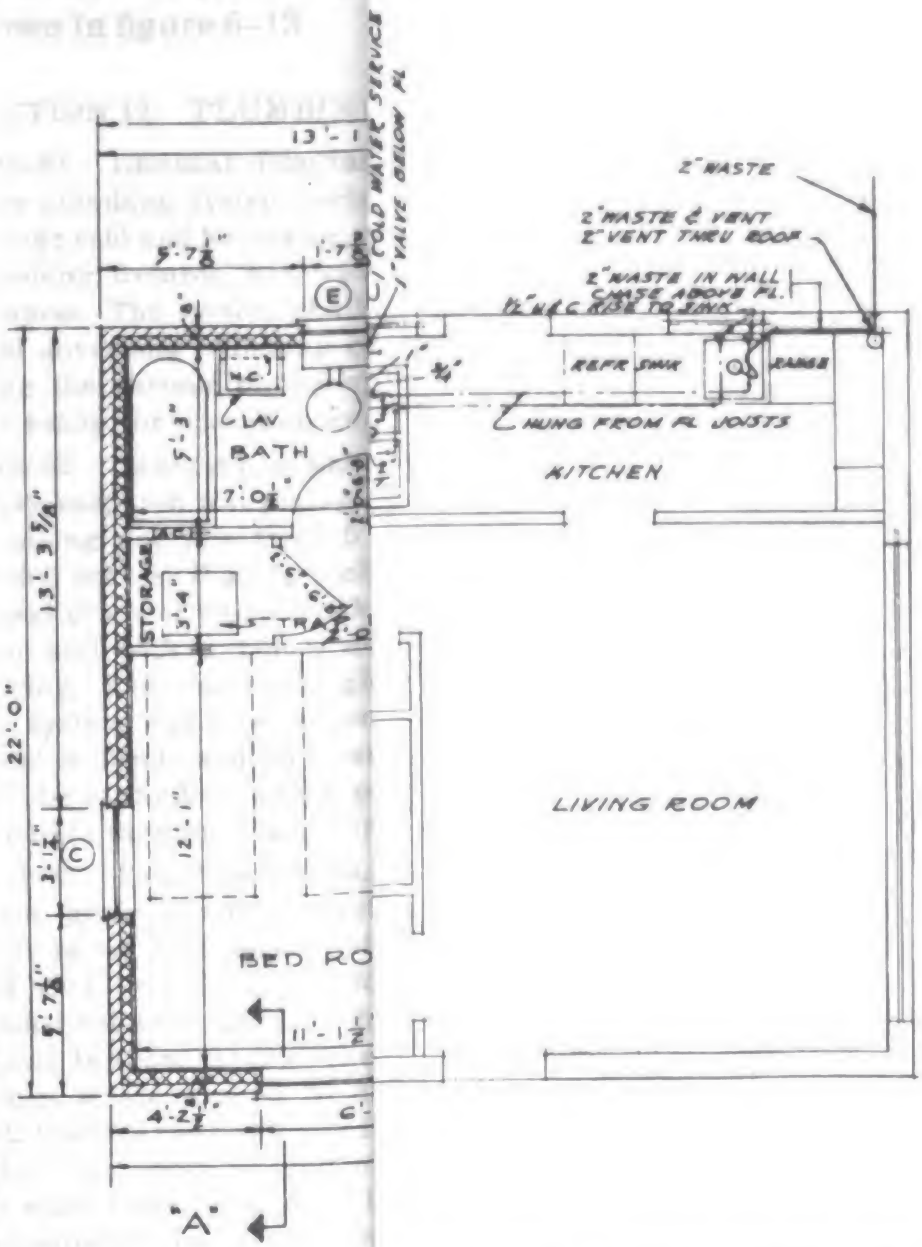


Figure 6–12.—A centrifugal pump.

Plumbing Layout

In figure 6–13, two floor plans for a small house are shown. One of these is the architectural floor plan, the other is the plumbing layout. The architectural plan has simply been repeated, with the dotted lines for movable furniture omitted. On this, the lines for the various piping systems and the symbols for fittings and valves have been drawn. Notes give the height of risers, stacks, and vents and other details pertinent to the construction. A legend of plumbing symbols used is included.

If this were an advanced base drawing, a bill of material might be included on the drawing, listing the pipe lengths, connections, valves, and fixtures. Since this is a bureau drawing for stateside use, the details of the



FLOOR P

SCALE: $\frac{1}{4}$" = 1'-

CATES HOT WATER PIPING (HW)

CATES GATE VALVE

CATES CHECK VALVE

VE

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plumbing are included in the specifications, and a materials list would be made up, working from both the specifications and the drawing. As you read the specifications for the plumbing which follow, study the drawing shown in figure 6–13.

SECTION 12. PLUMBING

12–01. GENERAL REQUIREMENTS.—The work consists of a complete plumbing system including the sanitary soil, waste, and vent piping; cold and hot water supply piping, water meter (if required), plumbing fixtures, hot water heater, and other necessary appurtenances. The system shall be inspected, tested, and approved by local governing plumbing codes before burying, concealing, or covering the various piping systems. Each system shall be complete and ready for operation except as specified or indicated otherwise.

12–02. SANITARY SEWER, below ground level, shall be of extra heavy cast iron soil piping and fittings of the bell-and-spigot type, extending not less than 5 feet beyond the foundation wall and graded not less than ⅛ inch per foot. The joint shall be made from a good grade of twisted oakum uniformly and well tamped into the joint and with a 1-inch depth of hot poured lead, made in one pouring, and caulked tight. All horizontal soil connections to the system shall be accomplished by Y-fittings or combination Y-and-⅛ bends and all changes in direction greater than ⅛-bends shall be of the long sweep pattern. Lines shall be well supported to eliminate sagging. Backfilling shall be well tamped in 6-inch layers.

12–03. SANITARY SEWER, ABOVE GROUND, shall be as specified for below ground, except wastelines and vent piping above ground shall be of zinc coated, standard-weight, screwed-end steel pipe and cast iron, recessed, long radius, screwed drainage fittings, graded not less than ⅛ inch per foot. The sanitary sewer vent shall extend full size through the roof for a distance of not less than 12 inches, where it shall be flashed with suitable corrosion resistant metal before the roofing is installed. A 4-inch cleanout shall be provided just above ground elevation at the base of the soil stack. All male screw ends shall be coated with a good grade pipe joint compound before entering into fittings. The bath tub trap shall be provided with a ¾-inch, brass, screw drain plug; all lines shall be properly supported from the floor joists with suitable hangers. Closet-bowl floor connection shall have a cast iron closet-bowl floor flange with provisions for anchoring the brass closet-bowl bolts and and an approved type of horn gasket. The finished joint shall be absolutely leak-proof and the bowl shall sit squarely on the finished floor.

12–04. WATER PIPING BURIED IN THE GROUND shall be jointless, type K, soft copper tubing. No "kinking" of the tube will be allowed.

12–05. WATER PIPING ABOVE GROUND shall be type "L," hard copper tubing with solder types of fittings, except that vertical lines may be of type "L," soft copper tubing. All tubing lines shall be properly anchored to the floor joists to eliminate "pipe hammering" and pitched to the main shutoff valve for draining when necessary. A hose bibb shall be provided at the rear of the building with a stop and waste located inside the foundation wall for winter cutoff and waste, and arranged for complete drainage of the line from the hose bibb. Slip joint connections will not be permitted below finished floor.

12–06. Fixtures shall be of a reliable manufacturer and shall be as follows:

(a) KITCHEN SINKS shall have a left hand drainboard and be of cast iron with a smooth, white, acid-resisting porcelain enamel finish, 54 inches long by 25 inches wide by 36 inches from floor to top of rim. The trim shall be chromium plated, including combination mixing faucets with soapdish, large basket-type strainer with 1½-inch tail piece, and a 1½-inch, wall-type P-trap. Hot and cold water supply lines in the sink cabinet shall be provided with copper tubing valves. The cabinet shall be of a heavy gage steel with a baked-on, white enamel finish and have at least two sliding drawers.

12–07. WATER HEATER shall be of the electrical storage type with a capacity of not less than 52 gallons. It shall be of an approved manufacturer with the underwriter's label attached. It shall be provided with two thermostatically operated heating elements; a 1500-watt element located near the top and a 1000-watt element located near the bottom of the tank. A ¾-inch, bronze, drain valve shall be provided at the extreme bottom of the tank, with a ¾-inch hose connection. A ½-inch, brass, combination temperature and pressure relief with a discharge extend to floor drain shall be furnished. A copper tubing valve shall be installed in the cold water supply. Electrical work shall conform to the local governing electrical codes.

12–08. A main shutoff valve shall be installed as indicated or specified. The 1-inch, main shutoff valve shall be accessible, of the stop and waste pattern with soldering type ends and the waste arranged for complete drainage of the entire water supply system.

12–09. WORKMANSHIP shall be performed in a first class manner, observing all standards of good installation practices.

(b) LAUNDRY TRAY shall be of the double-compartment, cement type, 48 inches long by 20 inches wide by 32 inches high from

floor to rim and be of a smooth cement mixture to withstand sudden temperature changes without cracking or leaking. Tubs shall have a metal guard around their rims. The laundry tray shall be complete with stand, combination mixing faucets with tray mounting brackets, 1½-inch tail pieces, and 1½-inch wall type P-trap. A copper tubing valve shall be provided in each supply line.

(c) WATER CLOSET shall be of white, vitreous china, close-coupled tank and bowl, complete with white seat and seat cover, and have a chromium, ⅜-inch, screwed, brass, floor supply line with a chromium I. P. valve.

(d) LAVATORY shall be cast iron with a white porcelain enameled finish. The trim shall be chromium plated and shall include combination mixing faucets with a 1¼-inch tail-piece, pop-up waste, 1¼-inch wall trap, and ⅜-inch, screwed, brass floor supplies with I. P. valves.

(e) TUB shall be built-in type, cast iron, with a white porcelain enameled finish. The trim shall be chromium plated and include a built-in wall-type faucet complete with shower attachments, a curtain rod and pins and a 1½-inch, trip-lever waste. Copper tubing valves shall be provided on each supply inside the wall access door.

12–10. TESTS shall be conducted on all plumbing systems to provide tightness of all piping joints. If leaks occur, they shall be repaired immediately and the tests repeated. The soil, waste, and vent systems shall be completely filled with water to the highest point before checking for leaks. The hot and cold water piping shall be tested with water at one and a half times the working pressure. After all tests have been proven satisfactory, all necessary adjustments on the faucets, traps, valves, and other specialties shall be checked in order that the entire system can be placed in normal operation.

12–11. INSULATION.—All piping and fittings subjected to freezing temperatures shall be adequately insulated with a suitable frost-proof covering well secured in place.

Takeoffs

In making takeoffs for bills of material, the normal procedure is to start at the farthest end from the outside connections or at the farthest fixture. Then take off the quantities of fixtures and fittings, counting the turns, and scale the piping. Each man will develop his own methodical method of working. You may find that you

prefer to take each system off separately, or you may take off the hot and cold water systems together.

It is important to remember that the fittings necessary to adapt the pipe size to a fixture are not shown on the drawing. The sizes of these fittings must be taken from the manufacturer's catalog which shows the fixture. There will be a variance between the size of the pipe supplied to the fixture and the fixture's tailpiece. For example, the pipe may be $\frac{1}{2}$ inch in diameter, while the fixture's tailpiece is $\frac{3}{8}$ inch.

Also note that on underground piping where there are long horizontal runs under the floor, cleanouts extending to the finished floor should be provided at approximately 30-foot intervals.

HEATING, VENTILATING, AND AIR CONDITIONING

Heat is considered to be expressed by molecular motion within a substance. The greater the motion, the greater the heat, and the less cohesion there is between the molecules. When the heat is great enough, it can change a solid to a liquid or a liquid to a gas. When water at the bottom of a vessel is heated, it will rise to the top and cooler water will take its place at the bottom. The heated water is lighter than the cool water. The same thing happens to air. It is on this principle that heating systems, especially gravity heating systems, are designed.

Heat passes from a body to a cooler body by means of conduction, convection, or radiation. CONDUCTION means that the heat is transferred from particle to particle in the same body or between bodies in contact. For example, if you touch something hot, the heat you feel has been conveyed by conduction. CONVECTION means that heat is transferred to flowing liquids or gases which come in contact with the heat source. It also means that this heat is transferred against the force of gravity, so that the heated fluid or gas rises. RADIATION means that rays of heat flow from a heated source and are received by other cooler bodies in the vicinity much as light rays are transferred from a source to surrounding objects.

No material medium is necessary and the heat is transferred in all directions, rather than upward as in convection.

In heating, ventilating, and air-conditioning, the relative humidity of the air is of great importance. Relative humidity is the ratio between the amount of moisture in the air and the amount of moisture necessary to saturate the air. Saturated air at 70° F. contains a different number of grains of moisture per pound than saturated air at 80° F. Also, saturated air at 70° F. has a vapor pressure of 0.429 psi and has 100 percent relative humidity (rh). Air the same temperature and with a vapor pressure of 0.215 psi has 50 percent rh. A vapor pressure of 0.215 psi is equivalent to the vapor pressure of saturated air at 50° F. Therefore, a sample of air at 75° F. and 50 percent rh cooled to 55° F. reaches the saturated state.

Further cooling produces a condition in which there is more moisture present than needed for saturation; and the excess separates from the air as condensate in the form of mist, fog, dew, or as droplets on the outside of a glass containing ice water. The temperature at which such condensation begins is the dewpoint.

In winter, air should be properly humidified for greatest comfort, and many heating, as well as air-conditioning, systems provide for this. If the air is too dry, it has a harmful effect on the respiratory organs so that they are more susceptible to disease. Also, if the air is too dry, it will absorb moisture from the skin. This evaporation process causes the skin to lose heat and produces a chilly effect, even when the temperature seems to be high enough.

In summer, when the temperature of the air rises, the relative humidity is often high as well. One of the means the body has for regulating its own temperature is the cooling effect of the evaporation of the moisture on the skin. However, when the relative humidity of the air is high, it will not absorb this moisture and considerable

discomfort will result. Therefore, in summer, the air should be properly dehumidified for greatest comfort.

Types of Heating Systems

The design of heating installations for buildings is one of the more complex fields of construction. The types of heating systems and variations of these basic types are numerous. For this reason, any discussion of heating systems must be limited. It is the DM's job not to design the heating system for a building but to complete a heating layout from notes and sketches provided by an engineer officer. To do this job, a draftsman must be familiar with the basic elements of heating systems and their graphical representation on a finished heating system layout.

In TP–Te–4, the types of heating systems to be used in the Navy are listed as:

1. Steam, either low pressure (LP), medium pressure (MP) or high pressure (HP)
2. Low-temperature water (LTW)
3. High-temperature water (HTW)
4. Hot air
5. Radiant
6. Electric
7. Split systems

Steam Heating Systems

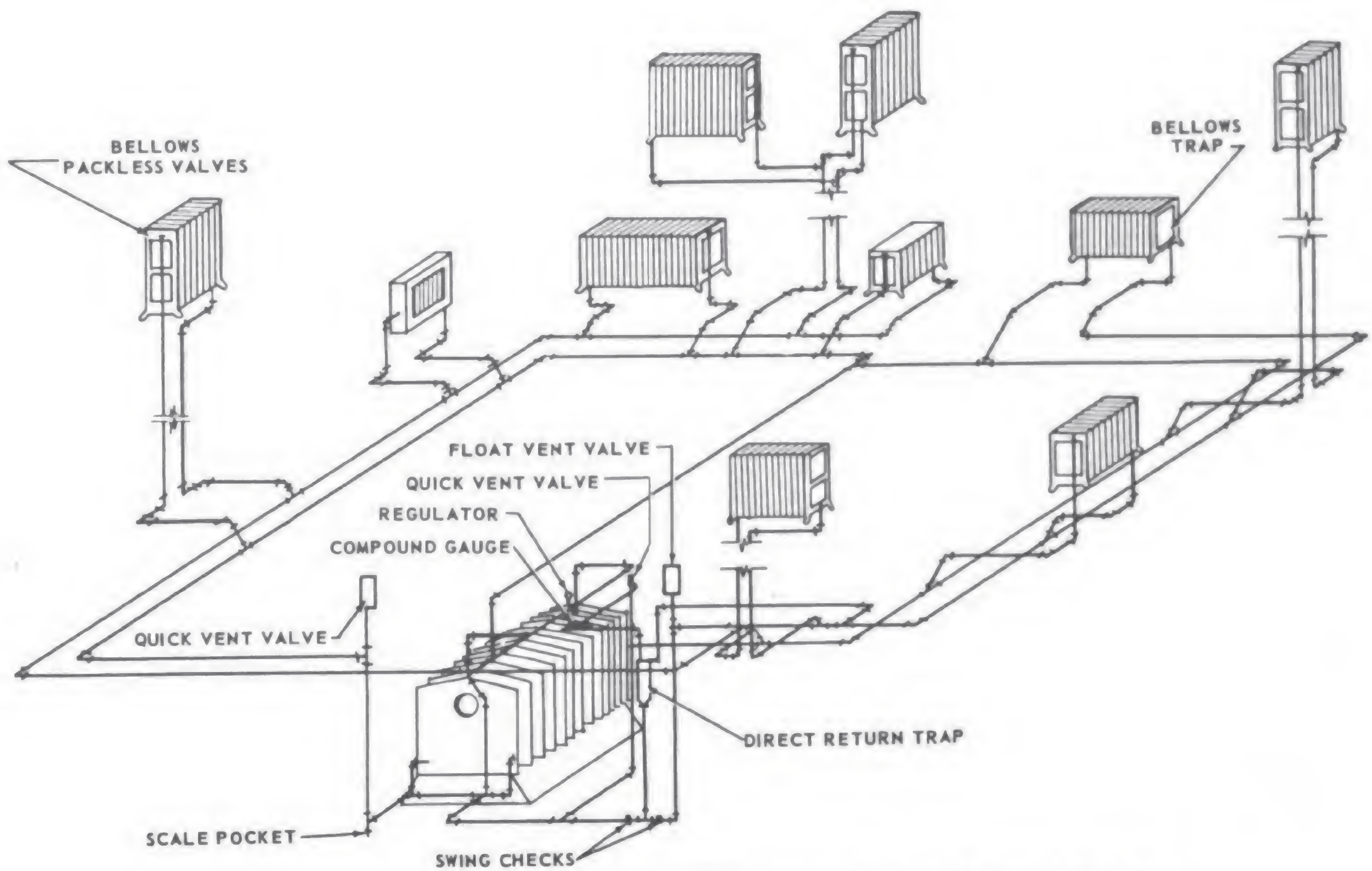
Steam heating systems may be one-pipe air-vent (gravity), vapor (gravity), or vacuum systems, and they may be upfeed or downfeed. One-pipe steam systems are not used in permanent structures. Low pressure steam, circulating through radiators or convectors, is used for heating most office buildings. Medium pressure steam from unit heaters is used for heating bakeries, laundries, hangars, and industrial buildings. High pressure steam is used mainly for process work and for conveying through a distance from a central heating plant.

In a one-pipe air-vent system, air which can cause a

cushion ahead of the steam and prevent its flowing, is removed by means of air valves installed on the radiators. A one-pipe system may be an upfeed or a downfeed system, and it always employs a gravity return. That is, the condensate flows back to the boiler and is not mechanically propelled. Most of the gravity return systems are one-pipe and are not recommended for permanent Navy buildings or for large buildings of any type.

In vapor systems, the design is intended to reduce steam pressure in the boiler and the amount of heat emitted from the radiators in mild weather, and to maintain boiler pressure and increase radiator heat in cold weather. A vapor system of the two-pipe type is shown in figure 6–14. The radiator may be of the hot water type. It operates with very low steam pressures. Since air valves on the radiators on the two-pipe system are eliminated, foul air or water cannot be discharged into occupied spaces. The steam enters at the top tapping of the radiator, rather than at the bottom tapping as in the one-pipe air-vent system through a graduated control valve. The temperature of the room may be controlled by the amount of steam admitted. Condensed steam and air are discharged through a thermostatic trap located at the lower tapping of the radiator into the dry return piping. These traps are designed to pass air and water but not steam. An air vent and check and an automatic return trap are installed in the dry return main which vents the air from the system, but prevents outside air from entering even when the fire in the boiler room dies down and the whole system is under a slight vacuum.

In a two-pipe vacuum system, a pump is used to draw air and condensate from the return lines. This creates a partial vacuum and helps the circulation in the system. This type of system is better for large buildings than either of the other two types, because of the pressure drop which may be expected in long runs of pipe. The radiators are equipped with graduated valves and traps like those in vapor systems. The vacuum pump on the



Courtesy of the American Technical Society.

Figure 6-14.—The Trane vapor heating system.

return contains an air liberating tank with a float controlled air vent.

Hot Water Heating Systems

Hot water heating systems provide for the circulation of water from a heater through pipes to radiators or convectors and back to the heater. A gravity system is rarely used today. Instead a pump, usually a centrifugal pump, is used to keep the water circulating.

There are three types of systems which can be used. The first, shown in figure 6–15, is the one-pipe system. Hot water is carried in a single main around the system and diverted to each radiator in turn. The water reaching the last radiator will not be as warm as that reaching the first, but in a small system, the difference is not great enough to be of importance.

Two-pipe systems are shown in figure 6–16. In these systems, the main carries only hot water, and the cool water from the radiators is returned to the heater by a return pipe. However, the two-pipe direct-return system in figure 6–16A should be avoided because of the inequality of the circuits through the various radiators. Special piping would have to be used and the first radiators in the system throttled to assure uniformity of radiator temperature. The reverse-return system in figure

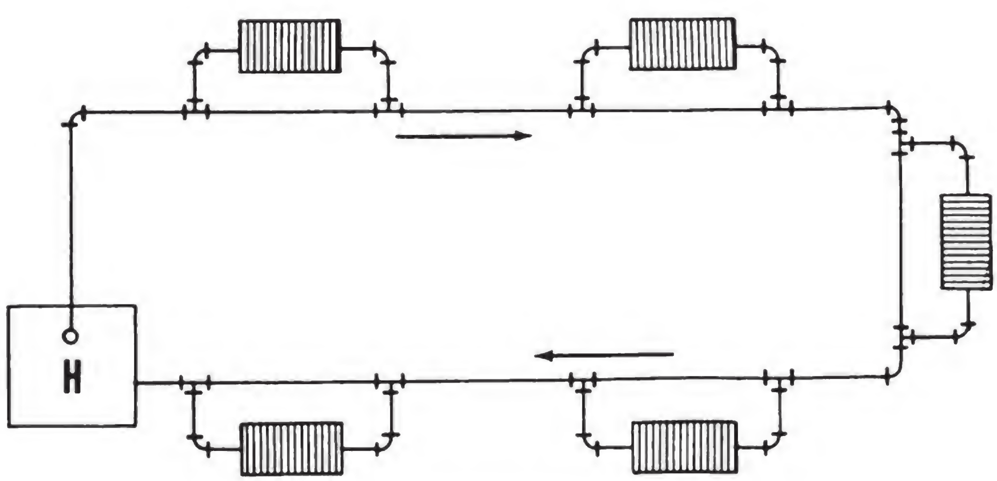


Figure 6–15.—One-pipe hot water system.

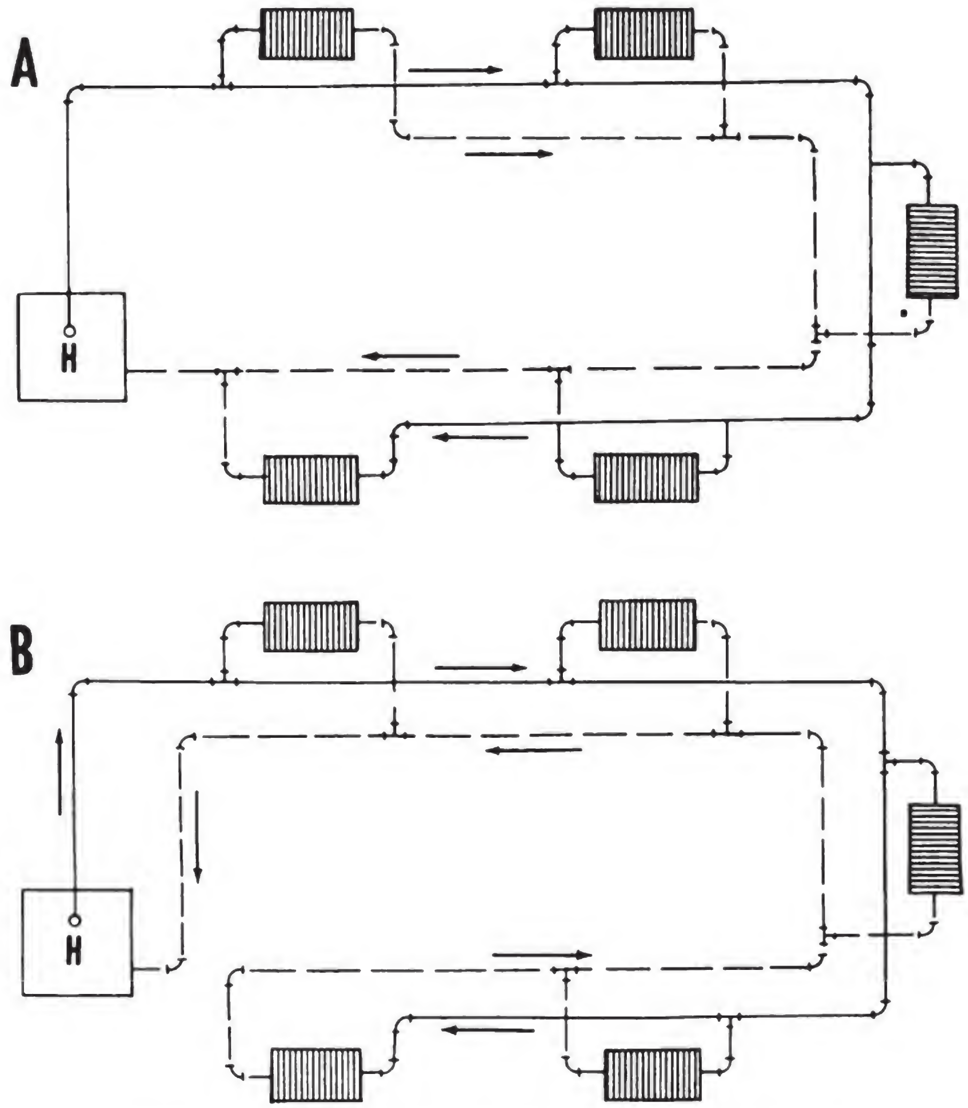


Figure 6–16.—A. Hot-water direct-return heating system. B. Reverse-return system.

6–16B, on the other hand, provides the same distance for the hot water and the cold water in each circuit. This permits faster heating with greater uniformity in radiator temperature.

Low-temperature water (LTW) systems are those in which the temperature of the circulating water does not exceed 220° F. High-temperature water (HTW) systems

are those in which the high temperature water is sometimes converted to low-temperature water or to steam by heat exchangers. HTW systems are the best for large or medium-sized central heating systems. Rehabilitation of old, steam-type central systems, new activities, and large expansions of existing activities are all ideally suited to HTW. The heat exchangers used to convert HTW to steam or LTW are identified by some authorities as reboilers or calorifiers.

Radiators and Convectors

The term RADIATOR is used to refer to a heating unit which is exposed to view in the space to be heated. Such units transfer heat by convection, as well as by radiation. (See fig. 6–17.)

The term CONVECTOR is used for units which, whether they are concealed or exposed, transfer heat largely or

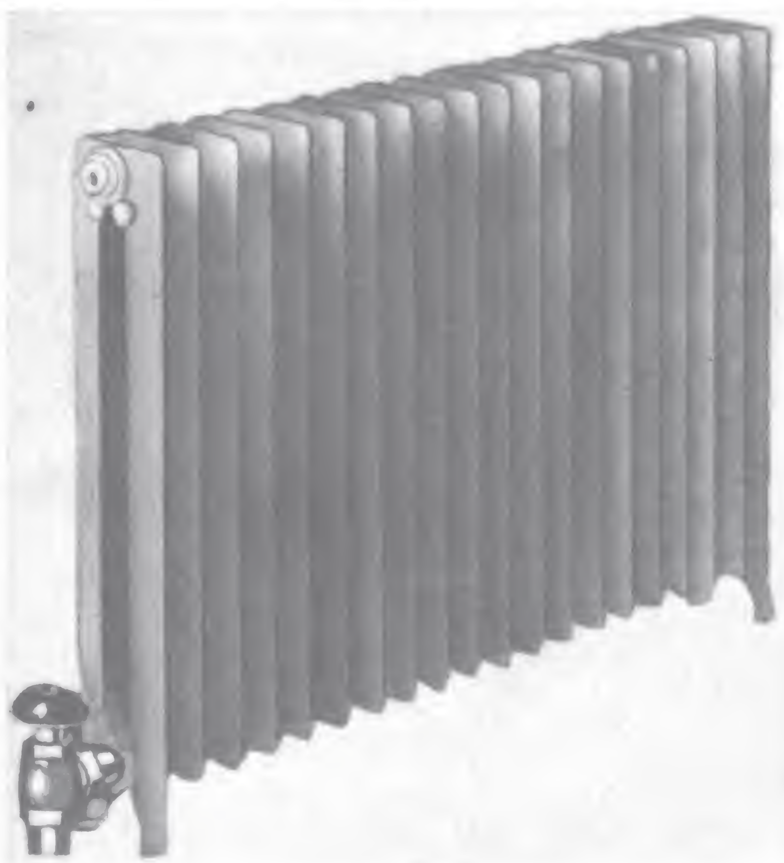


Figure 6–17.—Radiator.

altogether by convection. For example, when a radiator is enclosed, it transfers heat by convection, rather than by radiation, and therefore becomes a convector. (See fig. 6–18.)

Since hot air rises, radiators and convectors function most efficiently to heat a space when they are placed near the floor, rather than high on the walls. Usually they are placed beneath windows, where the heated air rising from them will mix with the cold air falling from the windows. Long, low, finned tubes at the baseboard level are the most efficient modern installations of this type. (See fig. 6–19.) Baseboard radiation is usually installed in continuous runs along the outside walls of the rooms either as hollow cast iron panels, or as ferrous or

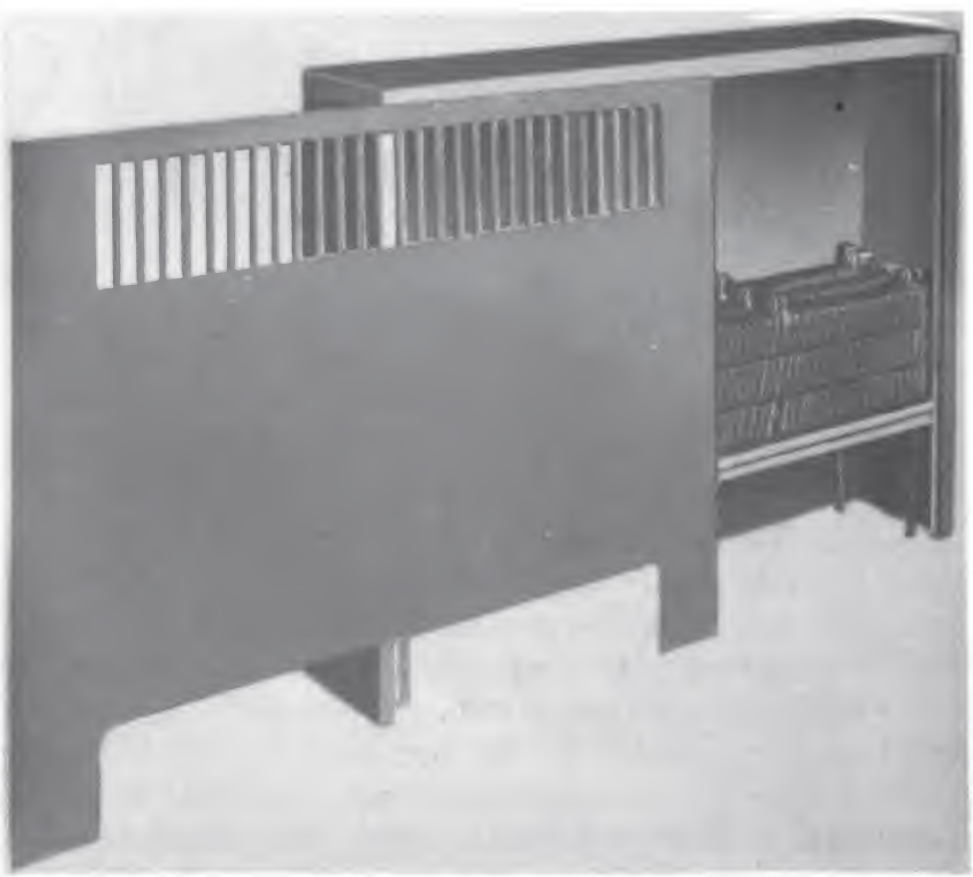
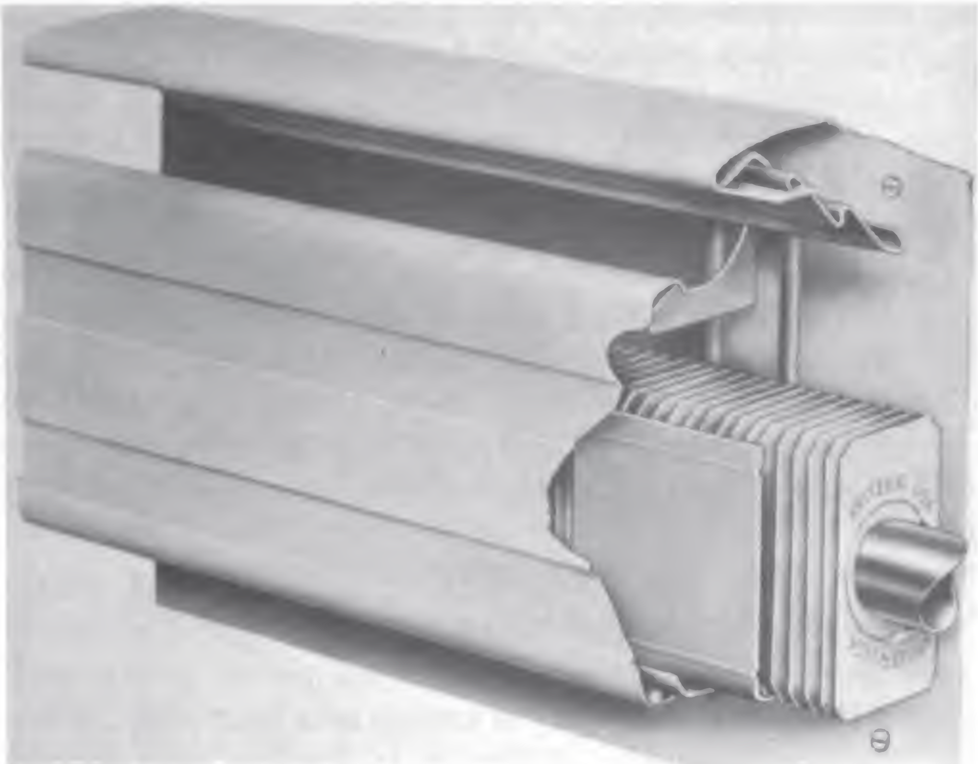


Figure 6–18.—Convector.



Courtesy of Kritzer Radiant Coils Inc.

Figure 6–19.—Finned tube.

nonferrous finned tubing within a formed metal container.

Boilers

Boilers for either low pressure steam or hot water heating systems may be made of cast iron or steel. Their capacities are in rating terms of the number of square feet of radiation that they are capable of providing or in Btu's, in manufacturers' catalogs. Square feet of radiation, actually square feet of equivalent direct radiation (EDR), refers to a unit of heat delivery (240 Btu's for steam or 150 Btu's for water) per hour. Radiators are rated in terms of EDR or Btu's, 1 square foot of equiva-

lent direct steam radiation being equal to an output capacity of 240 Btu's per hour and 1 square foot of equivalent direct hot water radiation being equal to a capacity of 150 Btu's. In other words, a boiler with a capacity of a given EDR will be able to serve a number of radiators with a total capacity of that given EDR.

Cast-iron boilers are made up of a series of hollow cast iron sections which contain the water. The sections may be circular and placed horizontally one above the other, or they may be rectangular and assembled vertically one after the other. Both types may be obtained with steel enameled jackets so that they appear very neat and compact.

Steel boilers are made with a shell of steel plates through which tubes run longitudinally. When the heated gases pass through the tubes to heat water in the shell around the tubes, the boiler is known as a FIRE TUBE. When the tubes contain the water, it is known as a WATER TUBE.

Hot Air Heating Systems

Hot air heating systems are those in which space heating or comfort heating is provided by distributing heated air through a duct system. The air is usually heated in a coal-, gas-, or oil-fired warm-air furnace, but it may also be heated by passing through steam- or water-heated coils. The air circulation in the duct system is motivated by forced-circulation fans. Gravity hot air systems are not used for permanent construction. Perimeter hot air systems may be used in small one-story residences and nonresidential structures.

The hot air heating system shown in figure 6–20 is composed of a furnace, a bonnet, warm air ducts, warm air registers, return air registers, cold air return ducts, and a fan or blower for forced circulation. The furnace includes the heat exchange surface, a combustion chamber, and a jacket around the chamber in which the air is heated. Above the furnace is placed a bonnet or plenum

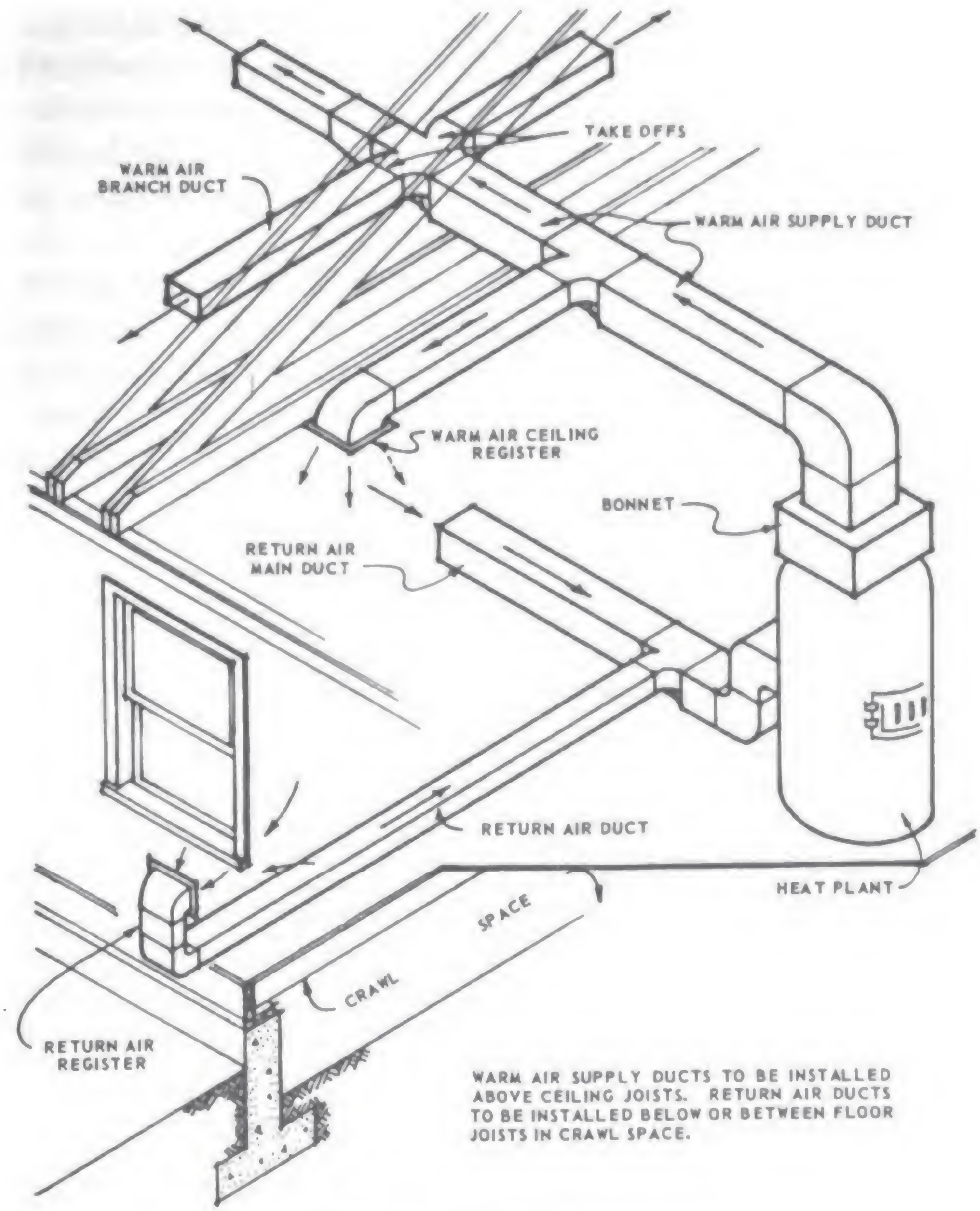


Figure 6–20.—Hot air heating system.

chamber, in which the heated air is collected for distribution to the various rooms.

The warm air is distributed through sheet metal ducts, which may be either round or rectangular in shape, and discharged into the room through warm air registers or grills. After the air is circulated through the room and loses part of its heat, it is returned to the plant through return air registers and ducts.

Most hot air systems do not use all of the same stale air for circulation. About 25 percent fresh air is introduced into the system. However, some heating designers maintain that fresh air seepage, or infiltration, into the building is adequate to maintain fresh air requirements in certain types of construction and occupancy.

Many design principles have been advanced in regards to the placement of registers and ducts in a building, but only one will be used in this discussion. All heating design stems from a basic concept of the comfort zone. Comfort zone is defined as the horizontal area from the top of an average man's head to his knees. (See fig. 6–21.)

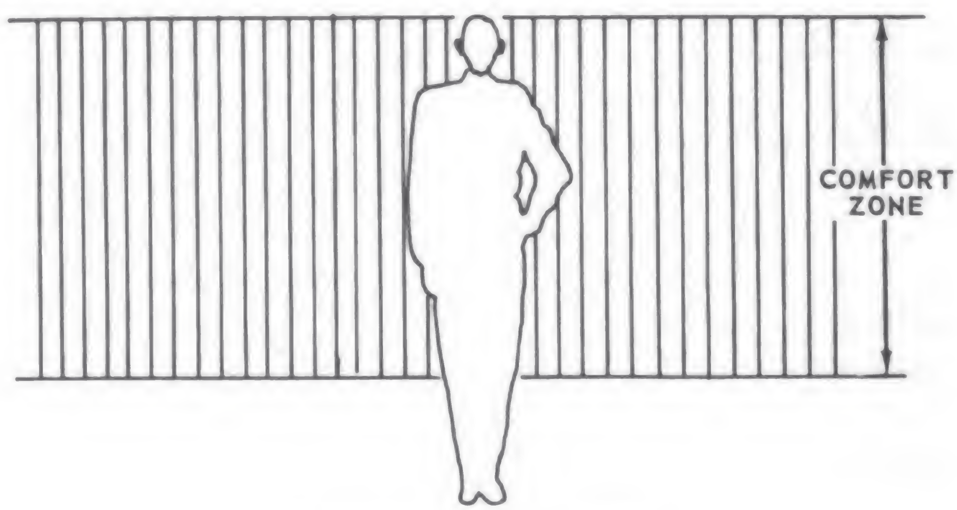


Figure 6–21.—The comfort zone.

Since the air used in hot air heating is discharged from the registers at a fairly high temperature, it is apparent that it would be uncomfortable if this hot air were blown on a person directly. Therefore, registers are usually placed below the comfort zone, so that no direct drafts of hot air are blown directly on room occupants. If the system is a combined one including both winter heating and summer cooling, registers are placed high in the wall so that the cool air being heavier than warm air, will be diffused through the warm air and not remain at the floor level.

In heating design, exterior walls are considered as cold walls, for in their immediate area, disagreeable drafts are incurred. For this reason, warm air systems are usually designed so that cold walls are blanketed with a layer of warm air. To make this possible, warm air registers are placed on interior walls and diffuse the air toward the cold exterior walls. These registers are located high on the wall or in the baseboard to satisfy the comfort-zone requirements.

Cold air return registers are always located at baseboard height, regardless of other design theories. The reason for this location is apparent. The heavy cool air, after giving up its heat to the room, collects in layers at the floor of the room. Cold air return registers located in the baseboard act as collectors for this cold air and return it to the heating plant through return ducts for reheating and recirculation.

Location of the furnace or heater room is also of great importance to warm air heating design. It is good design policy to locate the furnace room centrally in the building plan in order to equalize duct lengths. Good design also dictates that main (truck) ducts should run above a central corridor to equalize branch duct lengths to the individual rooms. Although it is true that heating design is not the draftsman's job, the foregoing general mechanical design considerations should always be foremost in his mind.

Hot air heating ducts are built of sheet metal—in rectangular or round sections. A discussion of air ducts is included in *Draftsman 2,* NavPers 10473.

Figure 6–22A illustrates a boot fitting from branch to stack—the stack terminating at a warm air register. Figure 6–22A also illustrates one method of changing the shape of a duct without changing its equivalent cross-sectional area or constricting the flow of air. Figure 6–22B shows an enclosed joist space used as a return duct. It is not advisable to use this method on warm air duct-work, because there is too much costly air leakage.

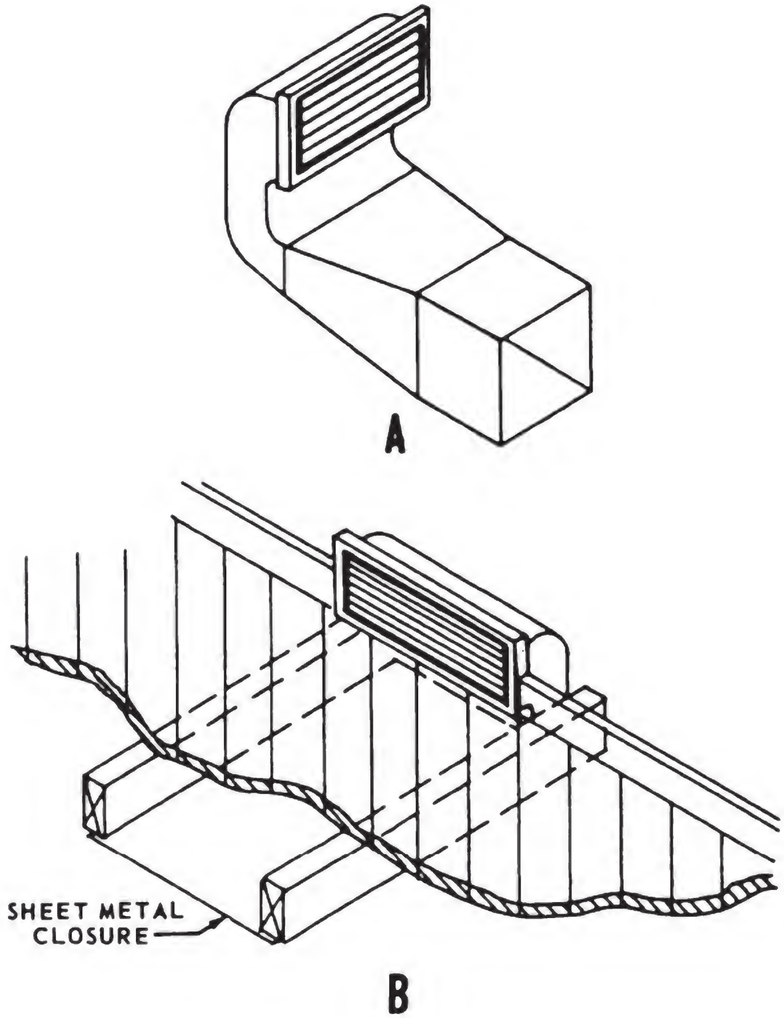


Figure 6–22.—A. Boot fitting from branch to stack.
B. Return air duct in joist space.

Radiant Heating

Radiant heating, also called panel heating, is a system of space heating in which large surfaces of rooms, such as floors, ceilings, walls, or a combination of these, operating at relatively low surface temperatures, are employed to produce comfort conditions. The heating medium may consist of forced-circulation warm water, warm air, or electricity. The means of carrying these media are embedded in or located behind the room finishes. Insulation is provided for radiant installations to prevent heat loss

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through concrete slabs on grade, through exterior walls, or into unoccupied spaces.

Electric Heating

Electric heating is used in small pumphouses, valve houses, guardhouses, or gatehouses, or similar small structures, when these buildings are too remote from a central heating distribution system or are too small to justify a conventional self-contained heating system. The heating elements may be either electric strip heaters or electric unit heaters.

Split Systems

Split systems are recommended for offices, school rooms, and other places of assembly where air for ventilation is required. In these systems, steam or hot-water radiation may be combined with a forced warm air heating and ventilating system.

Figure 6–23 shows a split system. The hospital is divided into five zones. Four are heated and cooled by air-conditioning systems. The fifth is heated by hot water radiators. No provision is made for cooling the spaces in this zone except through the use of exhaust fans. The reasons for this zoning are fairly apparent.

Surgery is supplied with its own system. This is desirable in order to prevent odors, fumes, or noise from being carried to other parts of the hospital. A separate system is used for the ward, because it requires heating and cooling at times when the other three air-conditioning systems may be turned off. Radiators and outside exhaust fans are provided, instead of an air-conditioning system, in the diet kitchen, utility room, and head. This prevents odors from being carried to other parts of the building, and also makes it possible to exhaust such odors from the spaces more efficiently.

Types of Ventilating Systems

Ventilating systems are required when it is necessary to provide sufficient fresh air for human comfort, to

remove noxious, irritating, or hazardous fumes, or to remove heat from high-temperature spaces. These systems may be natural, draft, or mechanically forced.

In natural ventilation, or gravity ventilation, the natural forces of wind and interior-exterior temperature differences are used to induce air circulation and removal. Generally, air is permitted to enter through openings at or near the floor level in a building and is allowed to escape through openings high in the walls or through openings or ventilators on the roof. Cessation of wind renders most natural ventilation systems inoperative or ineffective.

In mechanical ventilation, mechanical forces are used to induce positive air circulation within a building space. Air movement is created by fans or by fans combined with a supply or exhaust-duct system. Examples of both of these methods are shown in figure 6–23.

Air-Conditioning Systems

In a broad sense, air-conditioning may be defined as a method by which the temperature, moisture content, and movement and quality of the air in an enclosed space are maintained within required limits simultaneously. The purpose of air-conditioning is to provide comfort for people or to maintain atmospheric conditions conducive to production or to the making of products in quantity and standardized quality.

In all systems of air-conditioning, air is the exchange medium that conveys heat between the space to be kept conditioned and the cooling or heating equipment. Air also has the capacity to absorb and carry moisture as water vapor. When air holds all the water vapor it can, it is called saturated air. Summer air is usually too humid for comfort, and therefore a summer air-conditioning system should be designed to both cool and dehumidify the air. Heated winter air, on the other hand,

usually is too dry, and therefore the system should be designed to both heat and humidify the air.

It is generally recognized that air introduced into a building or circulated in a space for ventilation should be cleaned, because dust, dirt, and smoke are always present to some degree in the atmosphere. Solid particles are usually removed by filtering the air with a dry viscous-coated or electrostatic filter. Vapor particles (odors) must be removed by sorbent filters, which are usually filled with an activated carbon.

Air-conditioning may be effected by room or space conditioning units or by a central system. Usually the units are used primarily for air conditioning small spaces, whereas a central system is installed for large spaces.

Refrigeration is sometimes used for comfort air conditioning, as well as for the preservation of chilled and frozen foods and for industrial applications. In all systems of refrigeration, a refrigerant such as freon or ammonia is used. The characteristic of a refrigerant is that it will remove heat by evaporation from a region to be cooled and when vapor is compressed it will release the heat, at a higher temperature, to be discharged to a stream of flowing air or water.

A layout for an air-conditioning system for a hospital is shown in figure 6–23. Figure 6–24 shows a simplified diagram of an air-conditioning unit. The fan located at the right draws the air into the supply duct, and air returning from the rooms is recirculated along with a regulated amount of air from outside. For winter air-conditioning, the fresh air is admitted through filters which eliminate dust. The mixed air is first warmed in passing over a bank of steam coils, called a preheater. This is necessary in order to prevent freezing the spray in the air washer. The spray is used to increase the moisture content of the air or, if the air has a high moisture content, to cool the air and condense a portion of the moisture out of it. The spray also functions as an air washer.

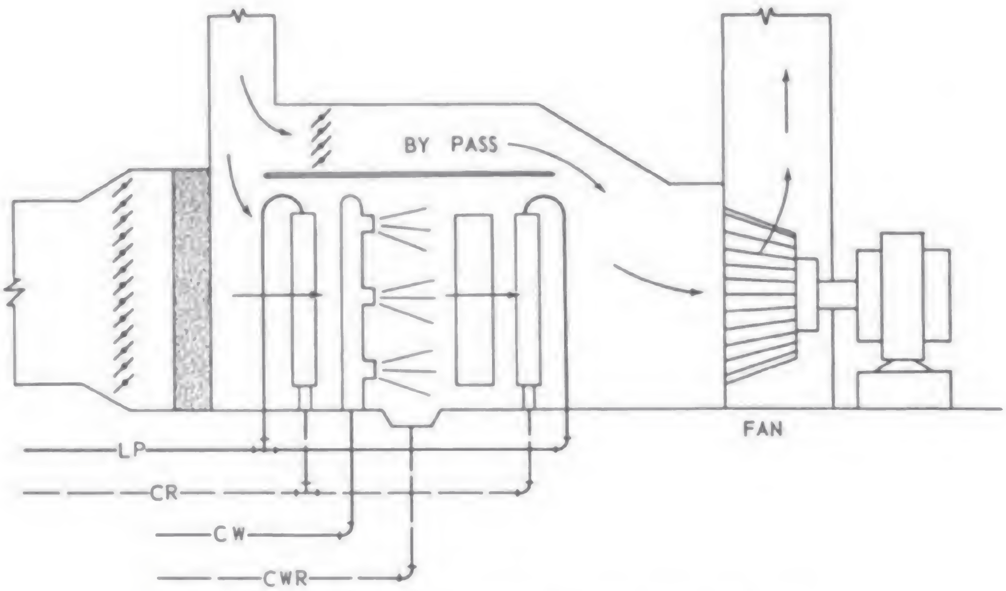


Figure 6–24.—Diagram of an air-conditioning unit.

The air then passes through a second heating element which reheats the air to the temperature desired.

A simple type of unit is available in which the air coming into the system passes over a finned tube coil containing cool water. As the air passes over the coil, it is cooled and also dehumidified in the process of cooling.

Layouts

As with plumbing system layouts, the layouts of heating, ventilating, and air-conditioning systems are usually done on a tracing of the floor plan of the building for which the systems are designed. Working from the rough design drawing, the draftsman draws the equipment and piping or ducts to the dimensions given. Usually, where equipment is concerned, he will be given the name of the article and any other pertinent details which will enable him to consult the proper manufacturer's catalog for the complete description. Boilers, radiators, fans, air-conditioning units, etc., may be drawn from the descrip-

tion of pictures given in the catalog. Mechanical symbols included in MIL–STD–17 should be used.

A separate drawing is made for the mechanical equipment, wherever its indication on the building detail drawing itself would be confusing. These drawings are kept as simple as possible. The building walls are usually shown with light lines, but no material indications are given. Door swings are not shown. Window openings are indicated. Otherwise the primary consideration of the drawing is the equipment shown on the plan.

Separate drawings are not made when space heaters are to be indicated on construction drawings, since a space heater installation is simple and small enough to be shown on the working drawing. When a space heater is indicated on construction drawings, the hearth should be shown on the plan, plus details if necessary. The fireproof wall covering, where required, should also be indicated and noted on the plan.

Mechanical equipment will be designed by an engineer officer or a heating engineer. He will furnish the sizes to the draftsman, with a rough sketch of the layout. From that point on, it is the DM's job to draw the heating layout in finished form, using standard symbols and notations.

Hot air ducts are indicated by solid lines, as shown in figure 6–25. When duct sizes are given, the standard accepted method is to list the horizontal dimension FIRST. This dimension gives the width of the duct. The duct size is noted on the duct as indicated in figure 6–25.

Cold air return ducts are indicated with dashed lines on the overlay. The same rules for duct dimensions are followed.

Warm air registers are located on the drawing and scaled to the actual size given. If ceiling diffusers are used, the neck dimensions are shown on the plan with the proper diffuser symbol. (See fig. 6–26.) If wall or baseboard registers are installed, face dimensions are

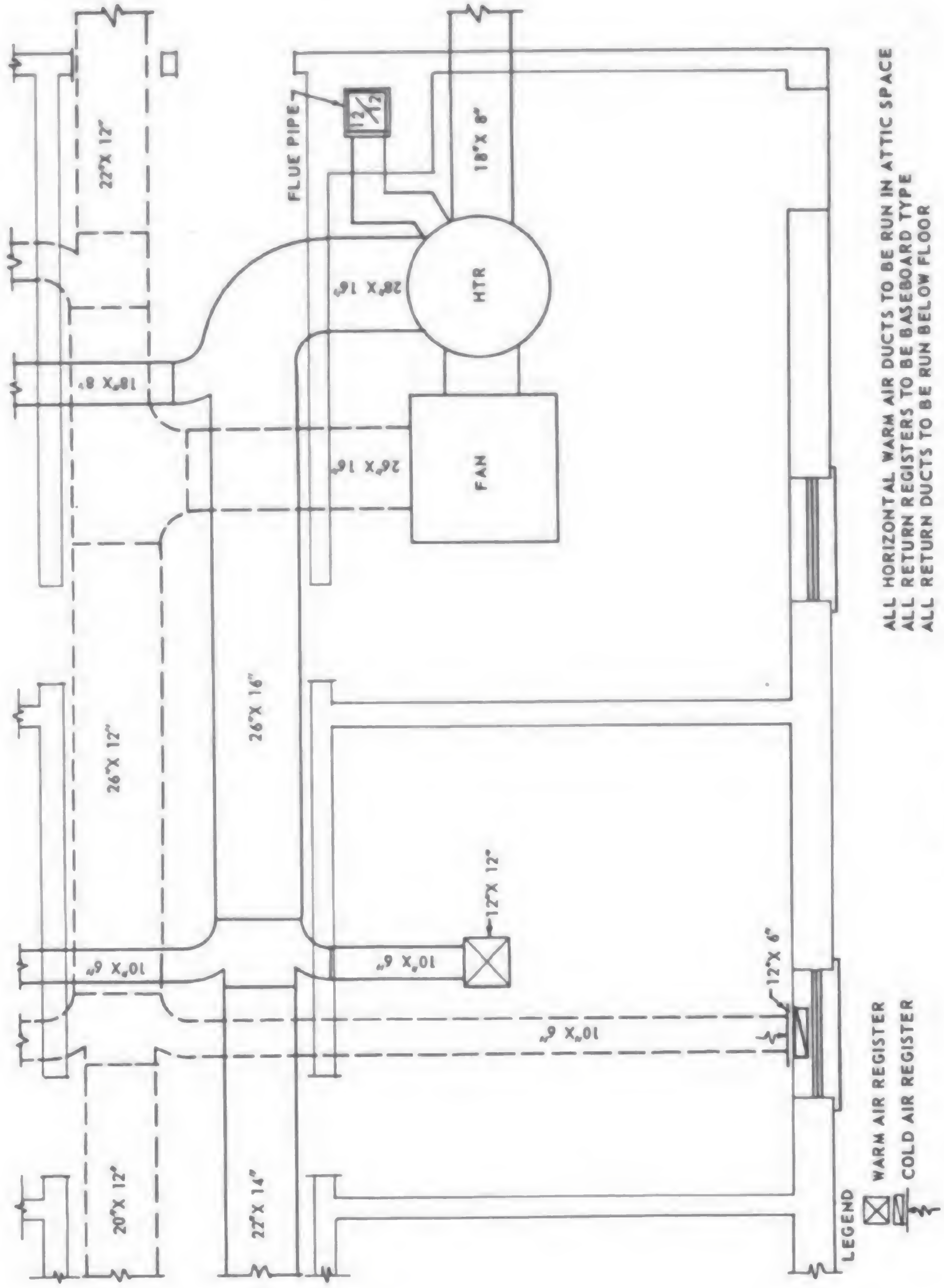


Figure 6-25.—Hot air heating layout.

shown. Stack depth depends on stud thickness, with the stack usually 3¼″ deep. Whether wall or baseboard registers are used, the face dimensions of the register are noted adjacent to the symbol. The heights of wall registers above finished floor line should be included in the notes.

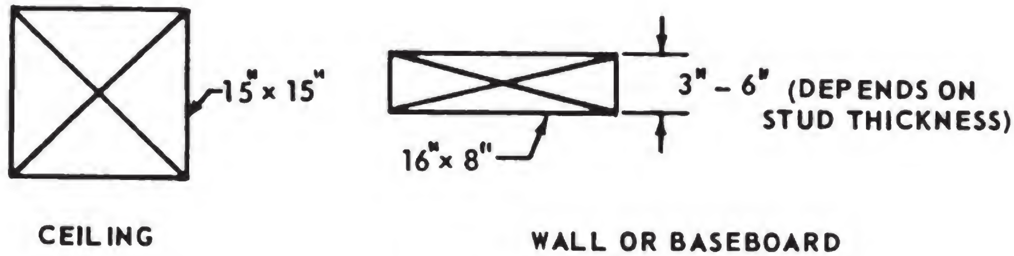


Figure 6–26.—A. Ceiling diffuser. B. Wall or baseboard register.

Return air registers are located from the sketch and the symbol drawn as indicated in figure 6–27. The horizontal face dimensions are scaled on the drawing, all registers being recessed into the wall. The face dimensions of the register are noted adjacent to the symbol.

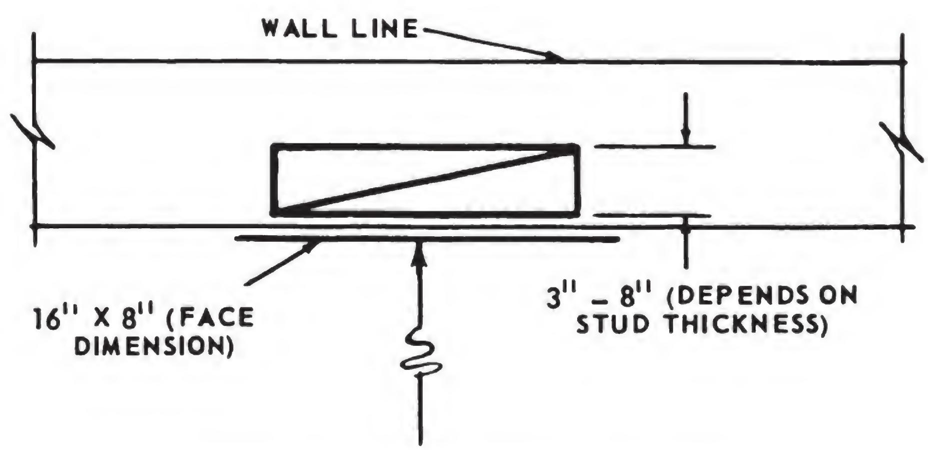


Figure 6–27.—Cold air return register symbol.

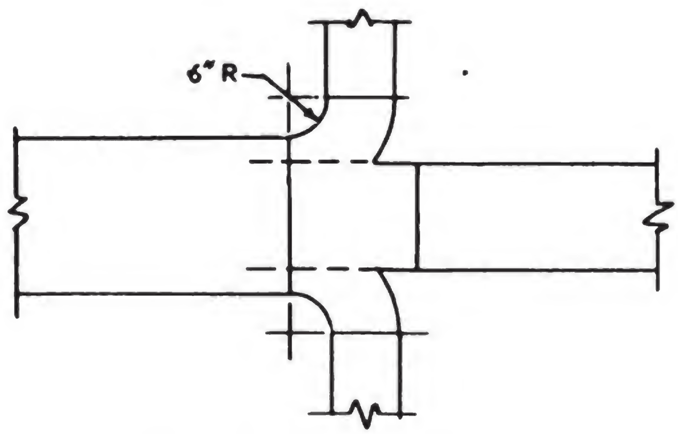


Figure 6–28.—Double branch takeoff.

When ducts are drawn on the layout, the draftsman should remember the direction of air flow, appearance, and economy. For example, when the double branch takeoff shown in figure 6–28 is drawn, an equal reduction on both sides of the main supply duct would be conducive to air flow—each branch forming a natural scoop. On duct layouts, the minimum inside radius of duct connections should be 6 inches, and the outside radius will be concentric to the inside smaller branch duct.

When the single branch takeoff is drawn, two considerations are paramount. First, the direction of air flow, and second, economy. To satisfy both these requirements, the reduction in size of the main trunk duct will

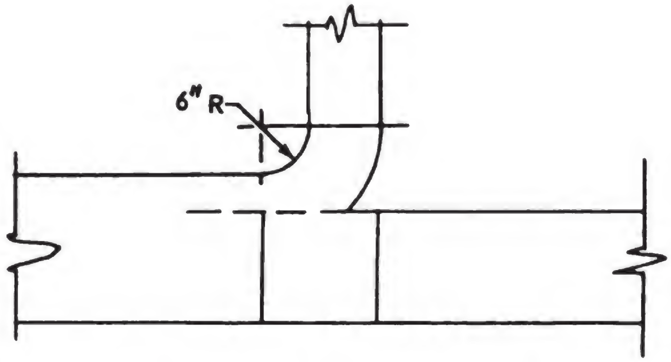


Figure 6–29.—Single branch takeoff.

be made from one side, keeping the other side straight to make the sheet metal work as simple and economical as possible. (See fig. 6–29.)

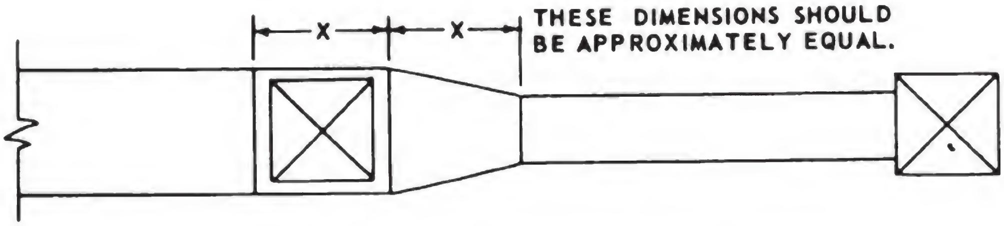


Figure 6–30.—Plan of ceiling registers in the same room.

Ceiling diffusers, if they are exposed in the same room, should be placed in a straight line. Any duct reductions should be made equally from both sides of the duct. In this case, appearance is the prime consideration, because ceiling diffusers should be in line with the walls. (See fig. 6–30.)

QUIZ

1. What does a standard plumbing system consist of?
2. What kinds of pipes are commonly used for water within a building?
3. What kind of pipe is used for waste or soil pipe below ground within the building and 5 feet outside the outer walls?
4. What kind of pipe is used for waste and vent stacks in the building?
5. How are pipe sizes up to 12 inches in diameter designated?
6. What is the taper of American National taper pipe threads?
7. How are pipe threads represented on drawings?
8. What is the main reason for using traps in plumbing systems?
9. Why are valves installed in plumbing systems?
10. What types of pumps are commonly used in plumbing systems?
11. What is the normal procedure followed in making takeoffs for bills of material?
12. What happens when water at the bottom of a vessel is heated and why?
13. Define RELATIVE HUMIDITY.
14. Why should the use of the two-pipe direct return hot-water heating system be avoided?
15. What is the most efficient modern method of installation for radiators or convectors?
16. (a) Why are warm air registers usually placed low in the wall? (b) Why are they placed in interior walls?
17. Why are cold air return registers located at baseboard height?
18. What is radiant heating?
19. What types of heating elements may be used in electric heating?
20. What is a split heating system?
21. When is a separate drawing made of the mechanical equipment for a building?

CHAPTER 7

STRUCTURAL DRAFTING

INTRODUCTION

As a DM 1 or DMS 1, you must be prepared to make drawings of advanced base and airfield structures and other architectural and structural drawings as assigned. It will also be your job to make quantity estimates from existing drawings and to check detail drawings made from your layouts. As a DM C or DMS C, you should understand the nomenclature and drafting conventions for ship and aeronautical structures as well.

You may find that as you acquire a knowledge of the various types of structures, you can make valuable suggestions concerning design. A knowledge of source material concerning structures and where to find data and drawings of similar structures will be of the greatest value to you.

NAVAL BASE STRUCTURES

Naval base structures are constructed on the same principles as civilian structures, except that certain specialized purpose structures may be included. The structures include administration buildings, harbor control and defense structures, communication structures, supply structures, ships' repair facilities, cargo handling structures, medical facilities, ordnance facilities, and personnel

facilities, such as camps, galleys, chapels, and recreational facilities.

The Bureau of Yards and Docks has prepared standard drawings for most of these structures. NavDocks P–140, *Advanced Base Drawings,* contains general drawings which may be adapted to the requirements of a particular advanced base. NavDocks P–272, *Definitive Drawings,* will also be of value. A current list of part of the standard, type, definitive, and other drawings available from the Bureau is contained in the latest edition of BuDocks Instruction 11012.8.

Besides these publications, the following technical publications published by the Bureau of Yards and Docks should be of value:

TP–Pw–1, *Storm Drainage Systems*
TP–Pw–2, *Mooring Guide,* vols. 1 and 2
TP–Pw–5, *Soil Conservation*
TP–Pw–6, *Railroad Trackage*
TP–Pw–7, *Petroleum Fuels and Lube Systems*
TP–Pw–8, *Waterfront and Harbor Facilities*
TP–Pw–10, *Drydocking Facilities,* vol. 3, Data Book
TP–Pw–11, *Arctic Engineering*
TP–Pw–12, *Water Supply Systems*
TP–Pw–15, *Sewerage Systems*
TP–Pw–16, *Storage Facilities*
TP–Pw–19, *Dredging*
TP–Pw–20, *Radio Communication Facilities*
TP–Pw–21, *Ordnance Facilities*
TP–Pw–22, *Medical and Dental Facilities*
TP–Pw–23, *Housing and Subsistence Facilities*
TP–Pw–24, *Administration and Security Facilities*
TP–Pw–27, *Cost Data for Public Works Construction.*
TP–Pw–29, *Snow Removal*
TP–Pw–30, *Maintenance and Operation of PW and PU (Interim)*
TP–Pu–1, *Refuse Disposal*

TP–Pu–3, *Power Generation and Distribution,* chapters 1,2,4,6,7, and 9
TP–Pu–4, *Fire Prevention and Fire Protection*
TP–PL–6, *Water Supply for Advanced Bases*
TP–PL–8, *Personnel Protective Shelters*
TP–PL–9, *Physical Security of Public Works*
TP–Te–1, *Surveys, Drawings, and Specifications*
TP–Te–3, *Basic Structural Engineering*

Architectural Graphic Standards by Ramsey and Sleeper is a definitive reference on building information, which is presented along with detail drawings. Other reference books and handbooks of value to those whose work is connected with construction are listed in appendix III in the back of this book.

Drawings

As a DMS, you may rarely be called on to make drawings for permanent structures. Your work is apt to be largely confined to temporary structures and drawings showing changes to permanent structures. You may also be required to make inspection diagrams and construction drawings for recreational facilities.

FLOOR PLAN.—When there are no representative plans in the files, you will be required to make floor plans for offices and shops. For example, plans may be required for installing a tile floor in an operating room or moving a partition in an office. Often this will involve taking the measurements of existing buildings. If you are in doubt as to the important measurements, consult the workmen who will do the work to be sure that you get the measurements they will need.

INSPECTION DIAGRAM.—Another type of drawing where measurements made on the spot are important is the inspection diagram. For example, every 2 years timber towers for radio stations must be checked. Measurements are taken to check alignment, and at each point on the diagram, indications must be made of the number of

inches that point is out of line. Also when timber trusses are used on buildings, it may be necessary to check alignment to determine how much the building may have settled. In this case, trusses and panel points are numbered on the plans and checked in turn.

RECORD (AS-BUILT) DRAWINGS.—One of your most important jobs will consist of making record drawings. According to TP–Te–1:

> Upon completion, or termination of completion, of the construction work on a project, the Bureau requires that any modifications, extensions, or omissions of or to the construction features of an original design be shown or otherwise indicated on the original drawing. The drawings then show actual, as-built conditions and are known as Record drawings.

They are also often referred to as "as-built" drawings.

Often in the course of building a structure, slight changes are made in the plans or construction, because of unforeseen conditions, variations in building materials, or similar reasons. In order to keep an accurate record of a structure under its jurisdiction, the Bureau of Yards and Docks must have a record of the structure as it was actually built. When it is completed, someone must take the original drawings and check them against the completed structure. The draftsman, because of his familiarity with drawings, is the logical one for this job. Whenever a change from the drawings has been made in the structure as built, mark the change clearly on the blueprint. Then corrections can be made on the original drawing or on the sepia print.

PRELIMINARY DRAWINGS.—Often when a construction project is contemplated, preliminary drawings are required in order to justify the work. These may be simple sketches, or they may be more developed schematics. If the drawings are to be used as a basis for bids for contracts, it is necessary that they be completed to the extent necessary to convey to the designer information on space and functional arrangements, type of construction and material, and special details required by the design. After the work is approved, a new drawing will usually

be made. If a contractor has been employed, he may also be required to furnish a new drawing.

ORIGINAL DRAWINGS.—You may also be required to make original drawings for relatively uncomplicated structures, such as loading platforms and ramps, or drawings for small additions to existing structures. Some pipelines are also structural jobs, with bridges across waterways or ravines.

Takeoffs

Conditions in the field may often require the draftsman to be an estimator. An estimation of the materials required for a building involves a knowledge of the standard units of purchase for the various materials, as well as an ability to determine from the drawings alone the amounts that will be needed.

The first step in making an estimation is the takeoff. This means that a listing of the various materials needed for the job is made directly from the detail drawings and specifications. The materials on this list are grouped as items, the total of each item found, and these totals reduced to customary units and number of units to be used on the job. Different materials are sold in different units, which are generally accepted in the trade, and when an item is listed in terms of the wrong unit, too much or too little of the particular item may be delivered at the job.

In takeoffs and material estimates, some common causes of error are:

1. Inaccurate arithmetic
2. Inaccurate copying
3. Omissions
4. Failure to allow for wastage or spare parts
5. Failure to check all computations and results

Estimators should always check themselves against items of the specifications to make sure that they have covered everything. If possible, the estimations, like the

drawings, should always be checked by someone other than the one who makes them.

STEEL CONSTRUCTION.—In takeoffs of structural steel, each kind of member in terms of structural shape, size, length in lineal feet, and weight in pounds or tons should be listed separately. Weights of any rolled steel shape or of a given quantity of rivets or bolts in a certain size may be obtained from any good construction handbook. Even where a structure is welded, a certain number of bolts, which will be placed in the framework and later removed, are often required. Steel for floating structures is listed in terms of long tons (l.t.), consisting of 2,240 pounds, whereas steel for buildings is listed in terms of the standard ton of 2,000 pounds.

It is easy to overlook such items as bearing plates, various field connections, gusset plates, field bolts, ties, beam separators, anchors, turnbuckles, etc. Some minor parts or details may not even be shown on the plans or mentioned in the specifications. For this reason the man who makes structural steel takeoffs must have a good working knowledge of structural steel construction.

WOOD CONSTRUCTION.—The materials for wood construction are various kind of lumber and necessary nails and hardware. The takeoff may be grouped into such divisions as framing timber, planking, finish materials, nails, hardware, etc.

Lumber is listed by board feet measure. One board foot is the equivalent of a board 1 foot long by 1 foot wide by 1 inch thick. The number of board feet in any piece of lumber is equal to the length in feet multiplied by the width in inches multiplied by the nominal thickness in inches with this product divided by 12, or

$$\text{foot board measure (fbm)} = \frac{L' \times W'' \times t''}{12}.$$

Standard lengths are in multiples of 2 feet and generally range from 10 to 20 feet. Standard widths are in multiples of 1 inch.

Trimming material, such as molding, is usually measured by the lineal foot (l.f.). Flooring, plywood, and shingles are sometimes measured by the square foot. Some articles are also measured by the piece.

Dressed lumber will be from 1/4 inch to 1/2 inch less than the nominal size in width and thickness. In estimating, allowance must be made for such things as sawing, planing, cutting, matching, and lapping. Allow 5 to 10 percent for waste in end cutting.

Nails are usually estimated in pounds at so many pounds to 1,000 feet board measure or at so many pounds to a square of 100 square feet, with consideration for the size of lumber and the kind of construction.

CONCRETE CONSTRUCTION.—The materials for concrete construction include cement, sand, gravel or crushed stone, reinforcing steel, finishing materials, materials for forms, and materials for protection against freezing. On some jobs, it is possible to re-use form lumber. If ready-made wood or metal forms are used, they will usually be classed as construction equipment which can be used over many times.

In making the takeoff for concrete work, a good method is to list separately each grade or mix of concrete used. After the takeoff is completed and the total yardage of each grade of concrete is found, the quantities of cement and other ingredients can be computed.

The term portland cement designates the common, gray cement that is used throughout the world to make concrete or mortar. There are many types of cement; however, standard portland cement and high-early-strength cement are the two classes most commonly used in the Navy. Standard portland cement is used for all concrete work when sufficient time is available for it to develop its full strength, while high-early-strength cement is used for construction work which must be completed in a short time. Concrete made with high-early cement will develop within 3 days about 75 percent of the strength developed in 28 days by concrete made with standard portland cement. A bag of cement contains 94 pounds, and

is 1 cubic foot in size. A barrel contains four bags of cement.

Concrete is measured as fixed or placed in the structure in cubic yards (or cubic feet). Moldings, curbs, gutters, lintels, and such work are often measured by lineal foot with the other dimensions given so that the number of cubic yards or cubic feet may be found. Concrete finishing is measured by the square foot or square yard.

The proportions of a concrete mix are usually expressed as three numbers, thus, 1:2:4, with the proportion of cement first, the proportion of sand second, and the proportion of gravel or crushed stone third. From these proportions, it is possible to find the quantities of the materials per cubic yard of finished concrete either by referring to tables in handbooks or by the use of formulas.

The amount of water in a concrete mix determines the strength of the cement. Concrete hardens because of a chemical reaction between the cement and the water. The aggregates are merely fills. A concrete with 5 gallons of water to a sack of cement is much stronger than one with 8 gallons to a sack. The proportion of water will not appear in the bill of materials, but it will appear in the specifications.

Reinforcing steel is usually estimated by weight. assuming that a square bar 1 inch by 1 inch by 12 inches long weighs 3.4 pounds. Reinforcing bars should be listed as plain bars, deformed bars, spirals, round or square bars of different diameters, and bent or straight bars. Steel fabric which is sold by the roll or sheet should be listed by size of mesh and weight per square foot, with the number of square feet given.

MASONRY.—To estimate the number of bricks required for a wall, the number of bricks per square foot of wall surface or the number of bricks per cubic foot of wall may be estimated. Allowance should be made for openings. When the number of bricks per square foot of wall surface is the basis for the estimate of the number of bricks required for a wall, the total must be multiplied

by the number of bricks thick the wall is, that is, if it is more than one brick thick.

Bricks range in size from 2 to 3 inches in thickness, $3\frac{1}{4}$ to $4\frac{1}{2}$ inches in width, $7\frac{1}{2}$ to 9 inches in length, and about 60 to 76 cubic inches in volume. The standard size is $2\frac{1}{4}$ by $3\frac{3}{4}$ by 8 inches, with a volume of 67.5 cubic inches, and 18 square inches on the face. The length may vary from $\frac{1}{8}$ inch to $\frac{3}{16}$ inches, depending upon the burning. The thickness of the joints between bricks may vary from $\frac{3}{16}$ to $\frac{3}{4}$ inch, with from $\frac{1}{4}$ to $\frac{1}{2}$ inch the most common thickness.

Walls of common brick increase in thickness by 4 or $4\frac{1}{2}$ inches. A wall 13 inches thick does not require any more brick than one 12 inches thick, so that this variation need not be considered when estimates are being made. In the past, estimators figured common brickwork on the basis of 7 or $7\frac{1}{2}$ brick to a square foot of 4- or $4\frac{1}{2}$-inch wall, 14 or 15 brick to a square foot of 8- or 9-inch wall, and 21 to $22\frac{1}{2}$ brick to a square foot of 12- or 13-inch wall. This method is still used where an overrun of brick is not too important, but a closer approximation may be achieved by the following method.

A brick 8 inches long plus a vertical, or END, mortar joint of $\frac{1}{4}$ inch equals a total length of $8\frac{1}{4}$ inches. A brick $2\frac{1}{4}$ inches high, plus a horizontal, or BED, mortar joint of $\frac{1}{2}$ inch makes a brick course with a height of $2\frac{3}{4}$ inches. Eight and $\frac{1}{4}$ inches times $2\frac{3}{4}$ inches equals $22\frac{11}{16}$ square inches for the total area on the face of the wall. To find the number of bricks per square foot of wall, divide 144 by $22\frac{11}{16}$. The result, 6.35 or $6\frac{1}{3}$, is the number of bricks per square foot of 4-inch or $4\frac{1}{2}$-inch wall. It is well to add $1\frac{1}{2}$ to 2 percent to the total estimate of the number of bricks required in order to allow for waste because of broken or faulty bricks.

Most mortar mixes include cement, lime, sand, and water. The mortar required for a structure of brick or stone varies widely, depending on the size of the brick or stone, the thickness of the joints, and the proportions

of the mix. A quantity estimate at best will be only approximate.

Concrete blocks vary from 4 to 12 inches in height, from 6 to 12 inches in thickness, and from 12 to 32 inches in length. The most common size, sometimes called 8 by 8 by 16, is actually 7¾ inches high, 8 inches thick, and 15¾ inches long, and varies in weight from 50 to 60 pounds each. Besides the regular blocks, there are half blocks, jamb blocks, and corner blocks. Concrete tile, usually hollow, varies in height from 3 to 12 inches, and in width from 3¾ to 12 inches, with a 12-inch length. Concrete brick are usually made standard size and are rarely hollow. The face of a gypsum block or tile is usually 12 by 30 inches, and it may vary from 2 to 8 inches, or even more, in thickness.

Rubble and squared stone masonry are measured by the cubic yard or foot, or by the PERCH. A perch of stone contains 24¾ cubic feet, except in certain states, chiefly west of the Mississippi, where a perch is considered to contain 16½ cubic feet. Cut stonework is measured by the cubic foot; stone trim by the cubic foot; and stone veneer by square foot or surface with the thickness given, or by cubic foot. The amount of mortar used will vary greatly depending on the stone. The materials in the mortar mix are cement, lime, sand, and such special ingredients as are required, and are usually given by volume.

ROOFING.—Roofing is generally estimated by a unit of 100 square feet which is called a SQUARE. In shingling, the estimate may be based on the bundle or on 1,000 shingles. The area covered by a given number of shingles will vary as much as 40 percent, depending on the lap and spacing. Flashing may be given by the piece, by a square foot, or by lineal foot; trim by lineal foot. Other materials used, besides the surface roofing materials, include nails and roofing paper and felt, downspouts and gutters. Eaves flashing is measured by the lineal foot, but the price is determined by the amount of metal constituting a lineal foot and in terms of the weight of the metal.

AIRFIELD STRUCTURES

Airfield structures include the airfield itself with runways, taxi ways, aprons, and hard stands, as well as hangars, control tower and operations buildings, parachute lofts, radio receiver and transmitter buildings, crash facilities, ordnance facilities, fuel storage and dispensing systems, and air cargo handling facilities. As with naval base structures, it will be most important for you to have access to representative drawings and for you to understand the terminology used.

The Bureau of Yards and Docks publication P–272, *Definitive Drawings,* contains representative drawings of buildings and other facilities. Airfield pavement is discussed in TP–Pw–4, *Airfield Pavement.* Other technical manuals of interest include TP–Pw–7, *Petroleum Fuels and Lube Systems,* TP–Pw–20, *Radio Communication Facilities,* and TP–Pw–21, *Ordnance Facilities,* as well as TP–Te–1, *Surveys, Drawings, and Specifications,* and TP–Te–3, *Basic Structural Engineering.*

Airfield pavement terminology is illustrated in figure 7–1. Takeoffs for material estimates may be made on the basis of area or volume formulas. Takeoffs for airfield structures are made as for naval base structures.

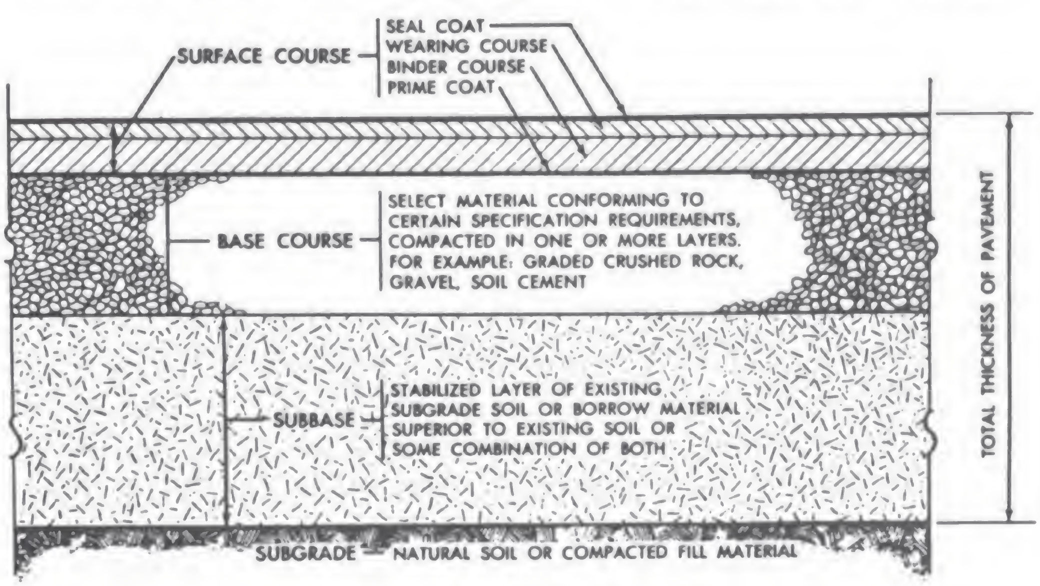


Figure 7–1.—Pavement terminology.

You should also know the exact meaning of such terms as landing strip, taxi strips, shoulder, apron, warm-up area, power check area, fill, and borrow material, which are defined in TP–Pw–4.

Drawings

You may be called upon to make the same type of structural drawings as for naval base structures. You may be required to make drawings of floor plans, record drawings, preliminary drawings, and drawings for temporary structures or for minor additions to structures. Besides these, you may be required to make drawings of the runways, taxi strips, and hardstandings. Usually when an airfield is built, a contractor will be in charge of the work, and will prepare master drawings for the construction of the landing strips, etc. However, you may be called on to make drawings showing proposed changes, such as changes in runway joints, or you may be required to make drawings showing increments of work, such as work to be done during a particular time or by a particular date or, in the case of a construction battalion, by a certain battalion.

SHIP STRUCTURES

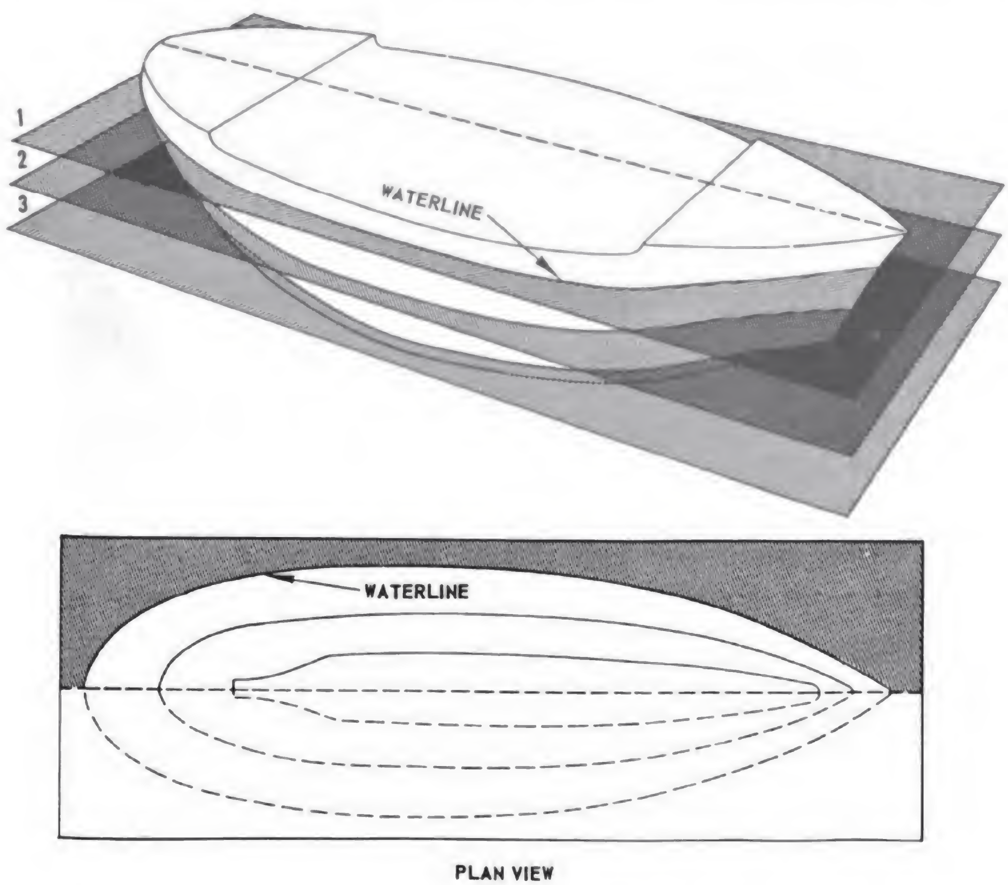
For terms used in reference to ship structures, obtain a copy of *Nomenclature of Naval Vessels* prepared under the direction of the Division of Personnel Supervision and Management of the Navy Department, June 1941.

Because of the shape of a naval vessel, the usual plan and elevation drawings are inadequate for the purpose of locating all points and defining all structures. Instead a system of fundamental lines and sections are used. The hull of a ship is considered to be cut by a series of horizontal, vertical, and transverse planes, with a result similar to the subdivision of an egg crate or an ice cube tray.

All vertical measurements aboard a ship are calculated from the plane of the BASE LINE (BL). The base line plane

extends horizontally from an established point at the bottom of the ship, usually along the top of the flat keel. For convenience in measuring above the base line, a series of WATERLINES (WL) are established. Each waterline is a certain number of feet from the base line. In figure 7–2, the water lines are shown at the intersection of the horizontal planes 1, 2, and 3 with the hull. When these waterlines are superimposed one upon another, they form the PLAN VIEW of the ship, as shown in the lower part of figure 7–2. The upper half of this plan as shown in the figure is known as the half breadth plan. The waterlines are also shown in figure 7–5.

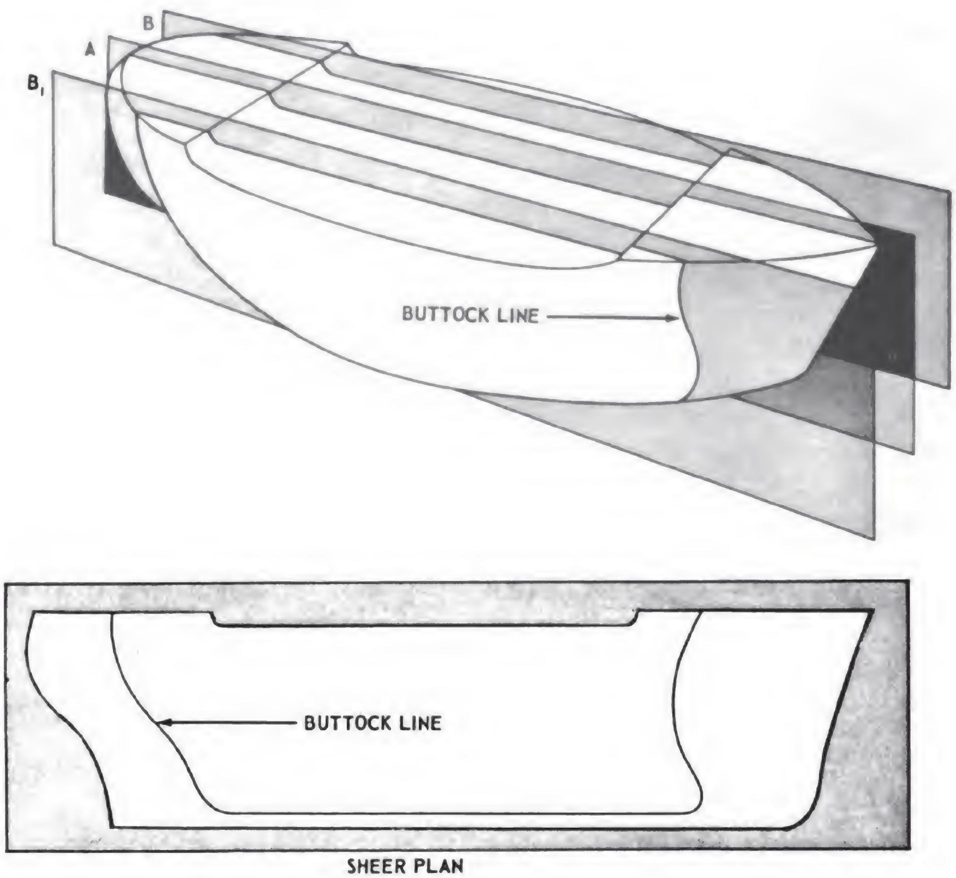
Horizontal measurements aboard a ship are calculated in terms of buttock lines and stations. Transverse meas-



Courtesy of the American Technical Society.

Figure 7–2.—Drawing showing horizontal planes and half-breadth plan.

urements are calculated from the CENTERLINE. In figure 7–3, the vertical plane A passes through the exact fore-and-aft centerline, and is termed the VERTICAL CENTERLINE PLANE of the ship. Its intersection with the hull shows the centerline profile and the exact contour of the stem and stern. Outboard from the centerline, a series of planes, shown by B and B′ in the figure, are called BUTTOCK PLANES. Their intersections with the hull form the buttock lines, which are labeled according to the number of feet between each and the centerline. Superimposing the buttock lines one upon another gives the sheer plan of the ship, as shown in the lower part of figure 7–3. These are also shown in figure 7–5.



Courtesy of the American Technical Society.

Figure 7–3.—Vertical centerline plane, buttock planes, and sheer plan.

In order to show the complete shape of the ship, another set of lines, called FRAME LINES are used between the forward and after prependiculars. They are numbered progressively from fore to aft. The distance between each of these lines varies with the different types

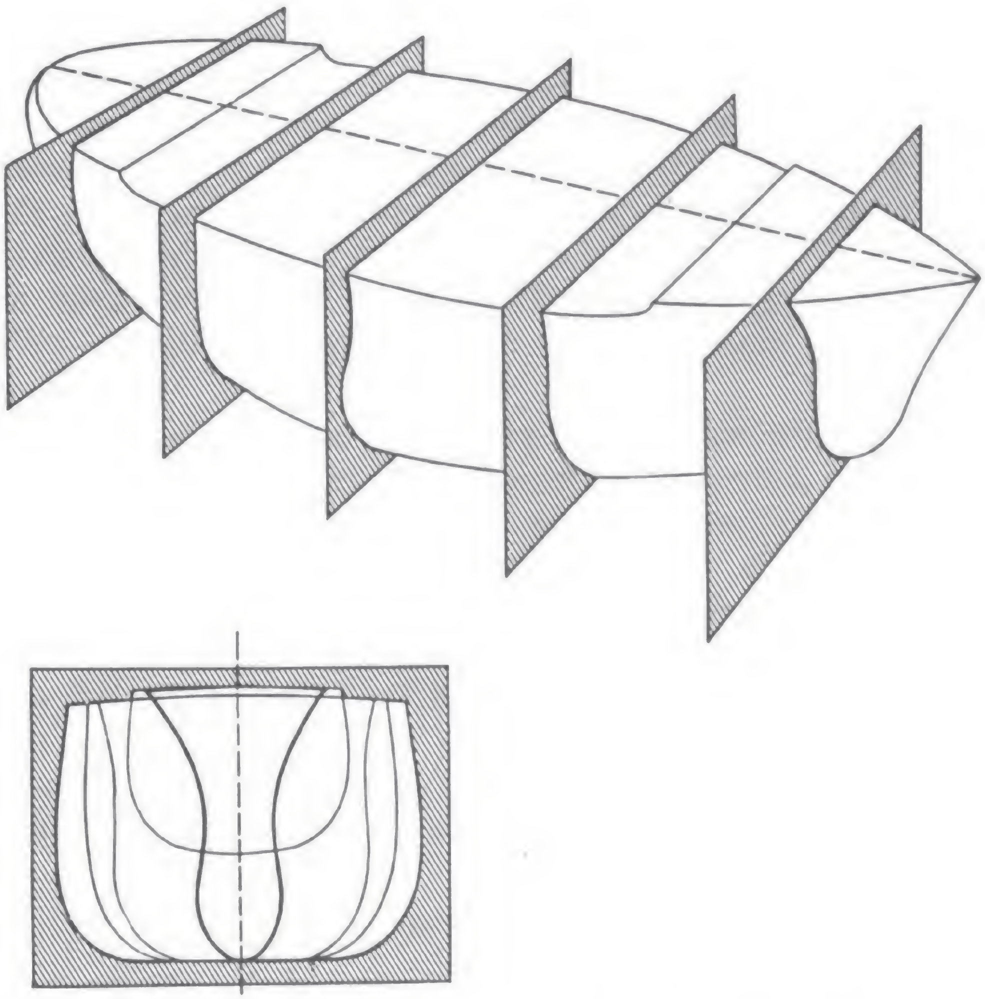


Figure 7–4.—Drawing showing transverse planes and body plan.

of ships. These lines are defined by the intersection of transverse planes with the hull of the ship, as shown in figure 7–4. Such an intersecting plane is called a STATION. The outline of the hull as intersected by a station is a SECTION. If the frame lines are shown superimposed one upon the other as in the lower portion of figure 7–4, the

resulting drawing is called the BODY PLAN of the ship. This is also shown in figure 7–5.

Some ship hulls are symmetrical with respect to the vertical centerline plane, only one side of the waterlines (port or starboard) need be shown to give the full shape of the hull. Therefore, only half of the plan view, or the HALF-BREADTH PLAN, is ordinarily used. (See upper sketch of fig. 7–6.) Since there is the same symmetry in the body plan, the right half of this plan shows the successive frame lines from the midship section forward, and the left hand side shows the frame lines from the midship section aft. This combination, shown in the middle of figure 7–6, makes for clarity, requiring fewer lines to represent the hull sections. The lower view of figure 7–6 shows the plan with the buttock lines in their true shape.

An additional set of planes is sometimes used, as shown in figure 7–7. These planes are perpendicular to the stations, intersect the vertical centerline plane at a point slightly below the main deck, and extend out through the hull at the turn of the bilge (the curved section of the hull joining the sides with the bottom). At their intersection with the hull, they form curved lines called the BILGE DIAGONALS. As can be seen, the various waterlines, stations, buttock lines, and bilge diagonals completely illustrate the shape of the proposed ship.

Terminology

In order to understand a discussion of ship design, you should have a comprehension of the following terms:

DESIGNER'S WATERLINE.—In the half-breadth plan, we generally speak of the waterlines as the lines developed by the intersections of successive horizontal planes with the hull of the ship, from the keel upward to the weather deck. Among this set of waterlines we have one at which the ship has been designed to float under normal loaded conditions. This waterline is called the DESIGNER'S WATERLINE (DWL). (See fig. 7–8.)

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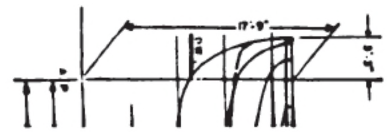


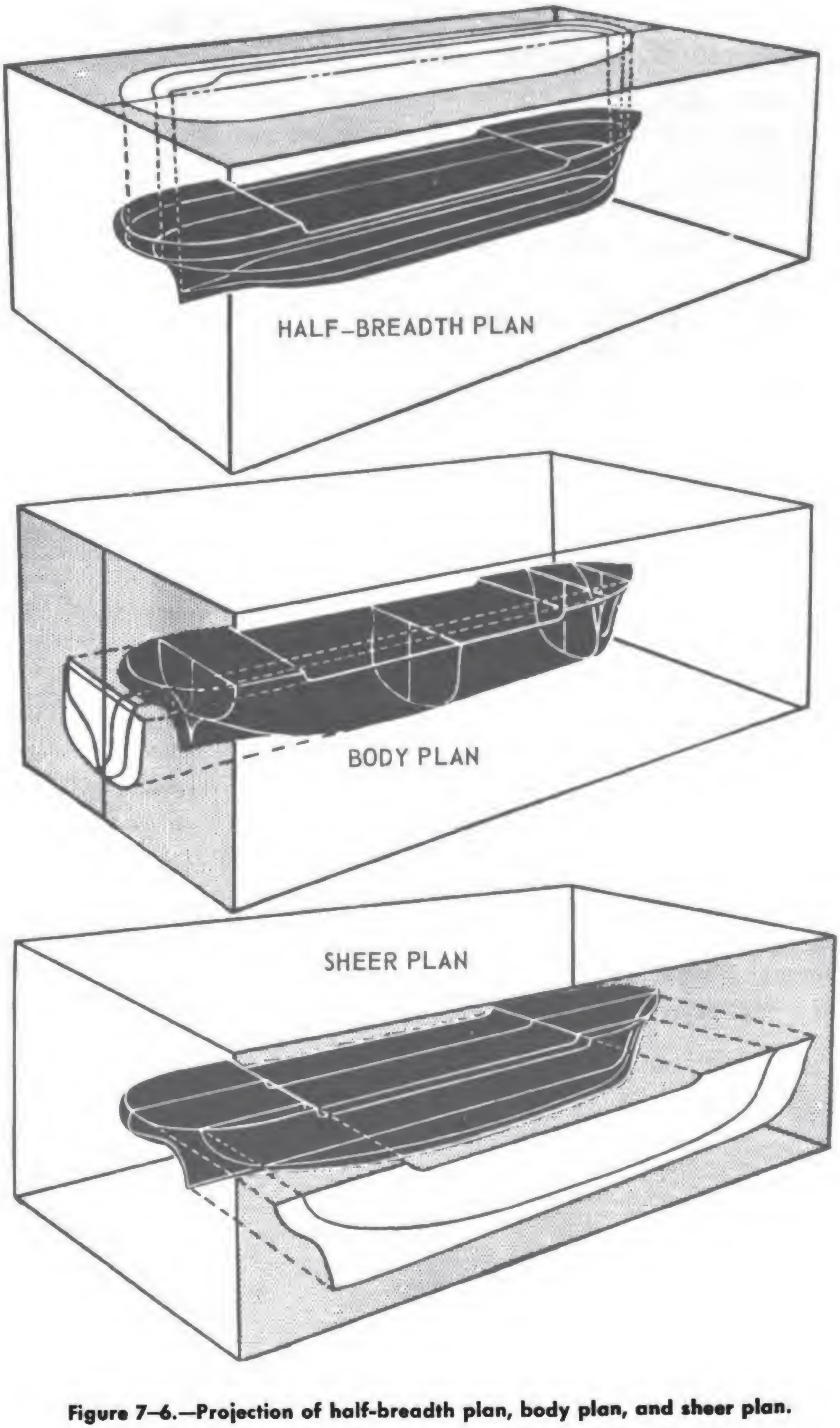


Figure 7–6.—Projection of half-breadth plan, body plan, and sheer plan.

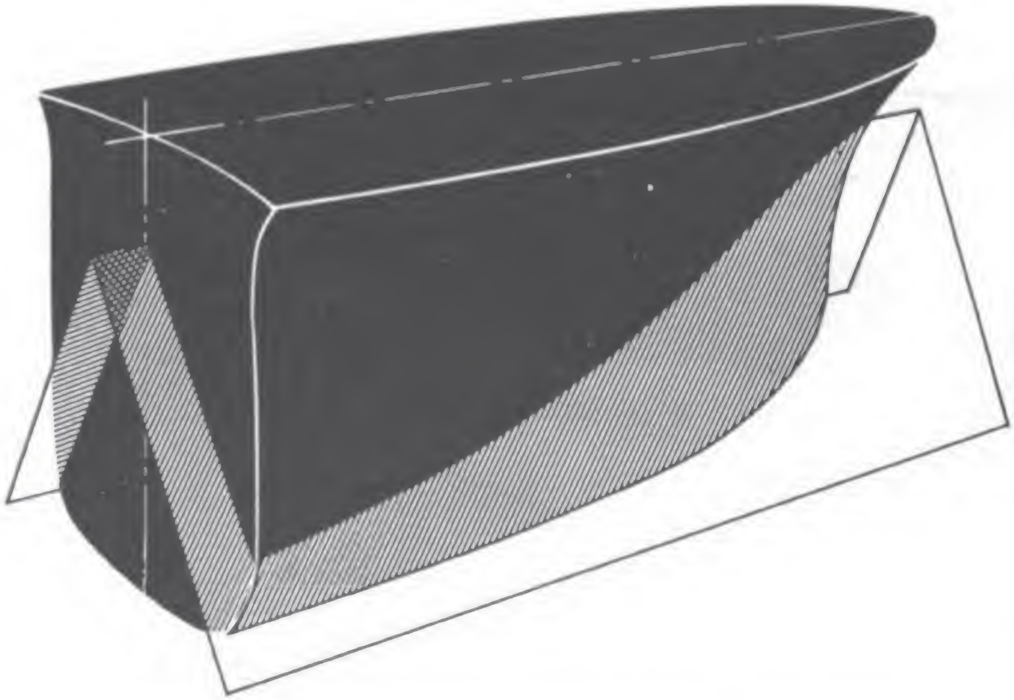


Figure 7–7.—Drawing showing projection of the bilge diagonals.

One common misconception is that the keel extends downward from the bottom of the ship. This is true only in the case of small boats with bar keels. On large ships, however, use is made of secondary keels outboard of the flat keel, called docking keels. These are relatively strong longitudinals, which simplify support of the ship when it is in drydock. Also, bilge keels are present on many larger ships. These are triangular or flat plate keels projecting from the hull at the turn of the bilge, running

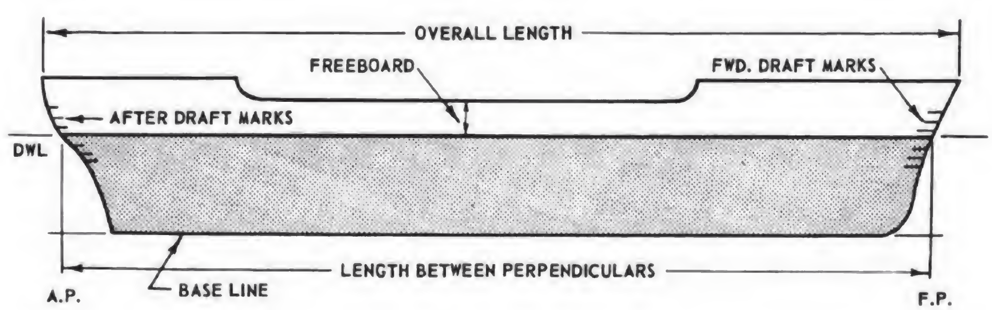


Figure 7–8.—Drawing illustrating use of certain terms.

fore-and-aft for approximately two-thirds the length of the ship, and serving to help reduce the roll of the ship in a seaway.

LENGTH of a ship is expressed in two ways: LENGTH OVER-ALL and LENGTH BETWEEN PERPENDICULARS. In the first case, the length is measured from the extreme forward end to the extreme after end of the ship. The length between perpendiculars extends from the FORWARD PERPENDICULAR (FP) to the AFTER PERPENDICULAR (AP), the perpendiculars being vertical lines passing through the line and the designer's waterline at its intersection with the bow and stern of the vessel in the sheer plan. Length between perpendiculars is sometimes called WATERLINE LENGTH. (See fig. 7–8.)

DRAFT, or vertical distance from the surface of the water to the bottom of the ship's keel, is measured at the bow and at the stern by scaled markings on the hull. Draft, then, is generally spoken of as DRAFT FORWARD and DRAFT AFT. The average of these two readings is known as MEAN DRAFT.

TRIM is defined as the angle to the horizontal at which a vessel floats. In general, this is the angle between the designer's waterline and the actual waterline at which the ship is floating. If the draft forward is greater then the draft aft, the trim of the ship is changed, the numerical value of this change is the algebraic difference of the changes in draft forward and aft.

As as example of the above statements: if a ship is trimmed so that she draws 21 feet 0 inches aft and 19 feet 0 inches forward, she is down by the stern and her mean draft is 20 feet 0 inches. By thus changing the trim, we have decreased the draft forward by 12 inches, and we have increased the draft aft by 12 inches. Thus, the change of trim is a plus 12 inches aft minus a negative 12 inches forward which equals 24 inches, as illustrated in figure 7–9.

DRAG.—Frequently, a ship's characteristics are improved if she has a slightly greater draft aft. When a

ship is so designed, she is said to have been designed with a drag.

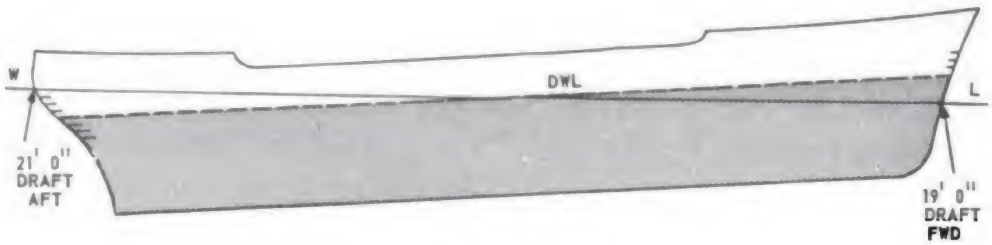


Figure 7–9.—Draft of a ship.

FREEBOARD AND SHEER.—Dealing with measurement of the above-water portion of the ship's hull, we have freeboard, or the vertical distance from the water to the weather-deck edge at any point. Sheer is the excess of freeboard forward or aft over the amidships.

BREADTH OF BEAM.—One never speaks of a ship's width, but rather of her breadth, or beam, which is the athwartship measurement taken at the broadest point of the hull.

CAMBER.—Decks are not ordinarily laid flat, but are built with a slight curvature, convex side up. This curvature, called camber, tends to strengthen the deck by the arched shape thus incorporated and also aids in drainage.

DISPLACEMENT.—When a ship is first floated, it will sink to a draft at which it displaces a weight of water equal to the weight of the ship. As Archimedes stated, "A floating body displaces its own weight in water." Therefore, we speak of a ship's weight as its displacement in tons. Displacement is always measured in long tons; that is, 1 ton equals 2,240 pounds. Armament treaties have set up the need for a more refined definition of the term DISPLACEMENT. Rather definite limits, therefore, have been assigned to the terms STANDARD DISPLACEMENT, LIGHT DISPLACEMENT, TRIAL DISPLACEMENT, and FULL-LOAD DISPLACEMENT, each of which limits the ship as to stores aboard, crew aboard, ammunition, fuel, etc., for the displacement given.

The basic structural component of a warship is flat steel used to form the shell, decks, and bulkheads of the ship. Such pieces are subdivided into two types: sheets and plates. Those having a weight of 5 pounds per square foot of surface or less are known as sheets. Those having a weight of over 5 pounds per square foot of surface are known as plates.

The major parts of the structural steel used in ship construction is plating which usually comes in rectangular shapes. The shell of the ship is made up of fore-and-aft rows of plating known as STRAKES. The junction of plates within a strake is a BUTT, while the connection between the plates of adjacent strakes is called a SEAM. These plates are fastened together to form seams and butts by means of riveting or welding.

In general, three types of plates are used in ship construction:

1. FLAT PLATES, which are the most common type on the sides, bottom, bulkheads, and decks of a vessel.

2. ROLLED PLATES are those having curvature in one dimension only. The most common uses are at the turn of the bilge. They are formed cold on a roller in a shop.

3. FURNACED PLATES are those plates having curvature in two or three dimensions. It is necessary in this case to heat the plate and shape it while hot. The plates around the outboard propeller shaft bearings, which are called BOSS PLATES, are usually furnaced because of the large amount of shaping necessary. The plates in the lower section of the bow are also usually furnaced plates.

The common structural shapes used in ship construction are shown in figure 7–10. Of these, the I-beam and T-bar are most widely employed. These shapes are rolled to size and form in the steel mills and are delivered ready for use. Shapes similar to those shown in figure 7–10, but of larger than normal manufacturing size are built up from plates and angles, as shown in figure 7–11.

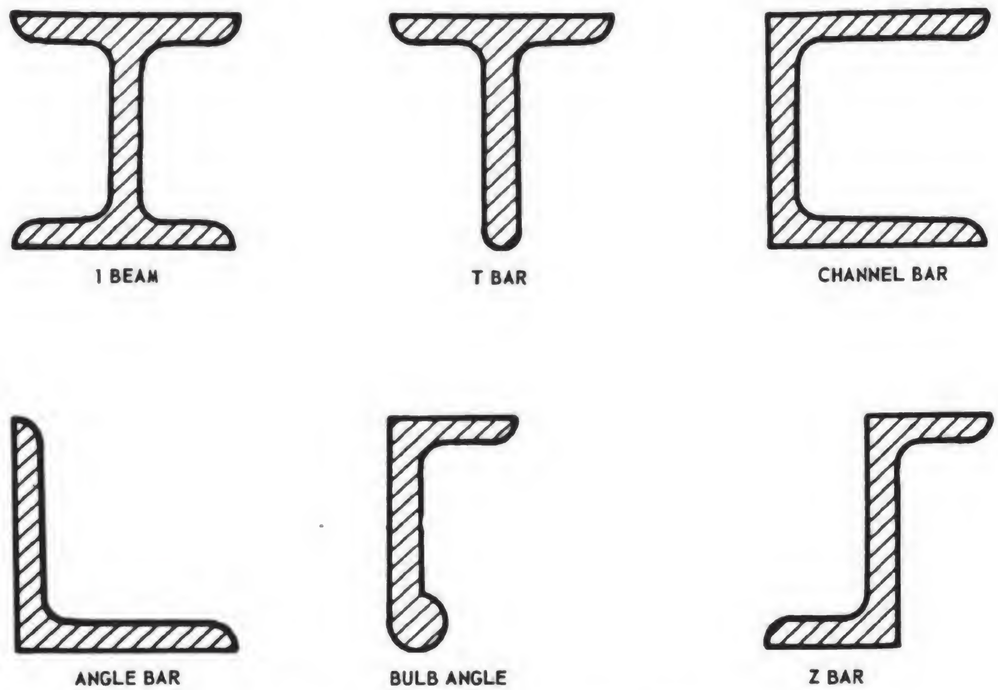


Figure 7–10.—Common structural shapes used in ship construction.

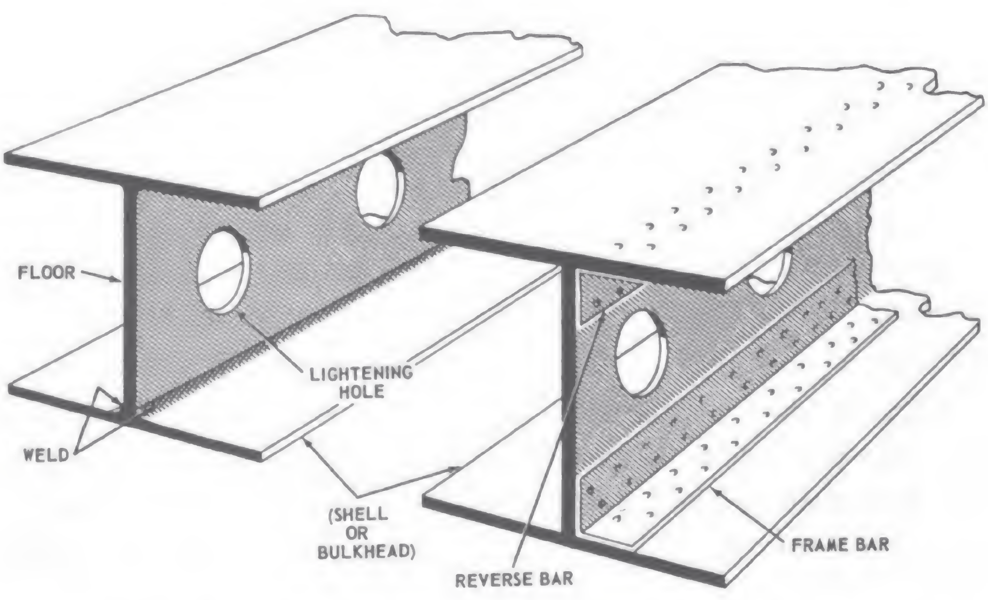


Figure 7–11.—Examples of built-up shapes; diagram on the left shows welded construction; diagram on right shows riveted construction.

The keel (K) of a ship is frequently referred to as the backbone of the hull. It is a built-up girder consisting of the CENTRAL VERTICAL KEEL (CVK), the DISHED or FLAT KEEL PLATE, and the RIDER PLATE or KEELSON PLATE. The flat keel or central bottom strake is always of extra strength although of less than standard breadth. Joining the flat keel is the bottom plating. Figure 7–12 illustrates the structure of a typical keel of an escort vessel.

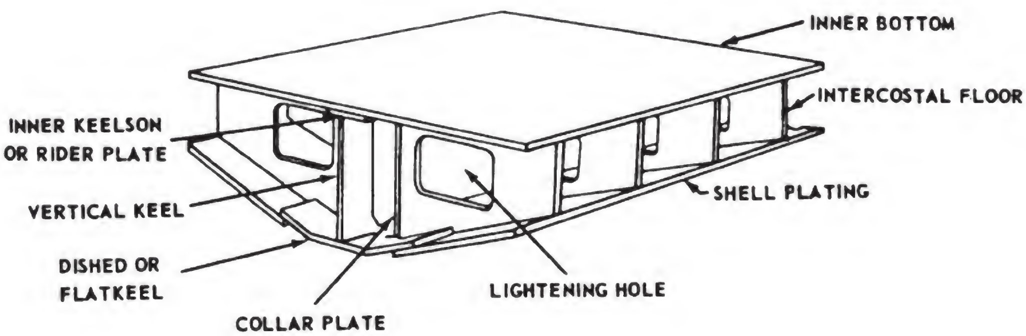


Figure 7–12.—Keel structure of an escort-type vessel.

Members extending to the sides of the vessel and joined perpendicularly to the central vertical keel are called FLOORS. Floors may be closed and watertight, or they may be open. (See fig. 7–13.) Extending the length of the vessel are other members called LONGITUDINALS. The floors and longitudinals divide the bottom of vessels into compartments. Steel plating over the floor and longitudinals forms the INNER BOTTOM, which may also be called the TANK DECK. On cargo ships, frames are installed on the sides as continuations of the floors. On cruisers, floors run up to the lowest complete deck, and above this deck, web frames are installed.

The outside plating of the ship is called the SHELL PLATING. The entire vessel may be considered a horizontal box girder, and shell plating contributes greatly to the strength of that girder. Figure 7–14 illustrates the types of STRAKES used in building up the shell. Each

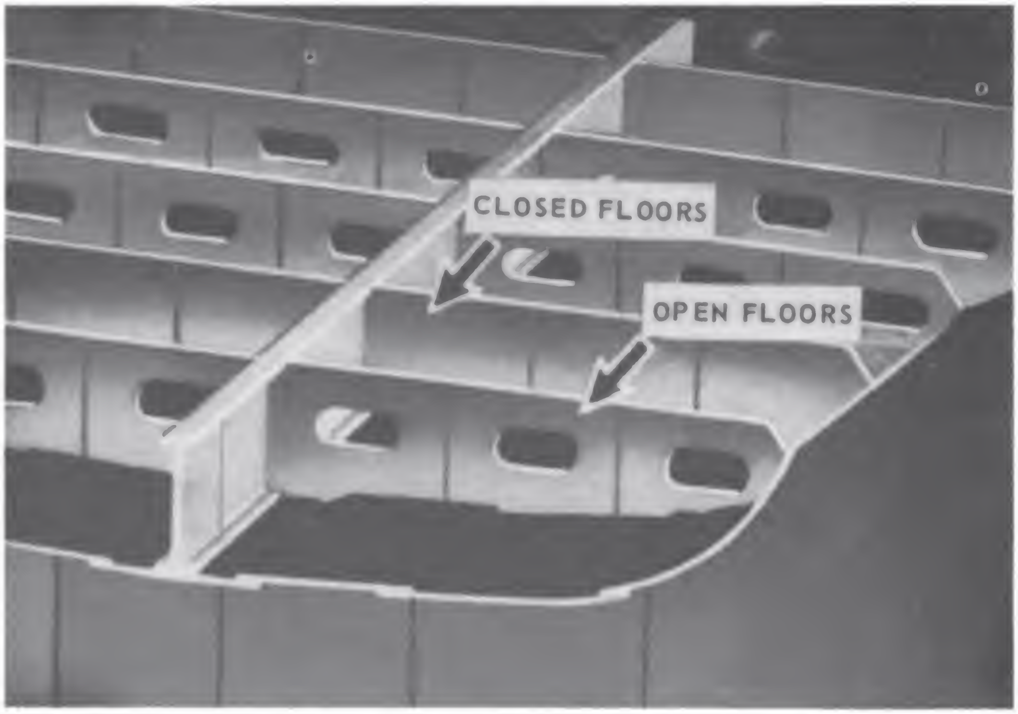


Figure 7–13.—Open and closed floors.

strake is lettered alphabetically, starting on each side of the keel and continuing to the sheer of the ship. The letter I is usually omitted to avoid its being confused with J. The A strakes, joining the flat keel, are called GARBOARD

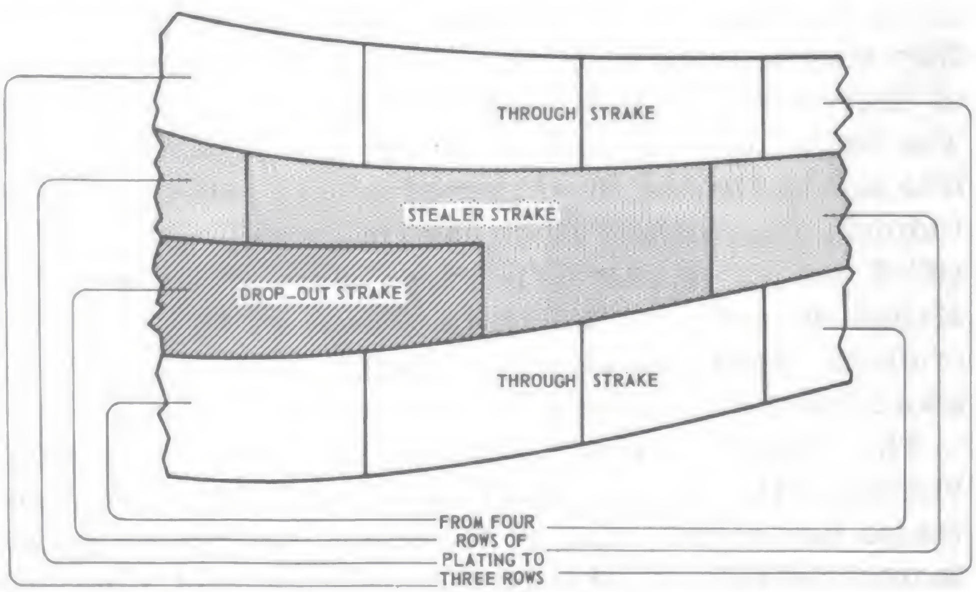


Figure 7–14.—Diagram showing types of strakes.

STRAKES. The final strake at the edge of the deck is called the SHEER STRAKE because it follows the sheer or longitudinal curve of the ship's profile.

Decks correspond to floors of a building, subdividing the structure horizontally. Decks stiffen a vessel longitudinally and transversely. Decks must be rigid in the horizontal plane and effectively fastened to sides and bulkheads. Considering a vessel as a girder, the upper decks form the main elements in the upper girder flange. But an important function of decks, besides constituting platforms for efficient utilization of space, is their contribution to the watertight integrity of the hull.

Another important strength function of decks is the support against racking (twisting) that they give to the ship. Certain decks are designed for protective purposes against plunging shell fire or aerial bombardment. These decks are designated as BALLISTIC DECKS, or protective or splinter decks, and are fitted with plating of extra strength and thickness. Where there are two such decks, the upper one is designated as a protective deck, and the other as the splinter deck.

In warship construction all decks are watertight. They generally extend the full width of the ship but not necessarily the full length. A COMPLETE DECK is one which extends the full length of the ship. A deck which does not extend the full length is known as a PARTIAL DECK. The MAIN DECK is always a complete deck. The first complete deck below the main deck is called the SECOND DECK. Where there are several complete decks below the main deck, they are known as the second deck, the third deck, etc. A partial deck which is above the lowest complete deck is known as a PLATFORM. Where there are two or more partial decks below the lowest complete deck, they are known as the FIRST PLATFORM, the SECOND PLATFORM, etc. A deck which is laid a small distance above the inner bottom in the machinery spaces is known as a FLAT, and has no camber. The flats in the machinery spaces are not watertight, and ordinarily are composed of separate plates which are easily removable.

A deck which has more than ordinary sheer is known as an INCLINED DECK. A partial deck above the main deck at the bow is known as the FORECASTLE DECK. A partial deck above the main deck at the stern is known as the POOP DECK. A partial deck above the main deck amidships is known as the UPPER DECK. However, the name upper deck is applied to any partial deck which extends from the waist to either bow or stern. A partial deck above the upper, main, forecastle, or poop deck, which does not extend to the side or does not connect with the shell plating, is called a SUPERSTRUCTURE DECK. If the structure extends above the superstructure deck, the additional decks are known by their functional purpose, such as the NAVIGATING BRIDGE, the FLAG AND SIGNAL BRIDGE, the GUN PLATFORM, etc. The fighting top extending above the superstructure is divided into levels by horizontal plating, and these levels are designated as the first level, second level, etc. The relationship of decks are shown in figure 7–15.

In order to reinforce the deck beams and relieve the deck beam brackets and side frames of the total load, vertical STANCHIONS, or pillars, are fitted between decks. These are of various sizes and construction, some being simple round sections, solid or hollow, and others being built up of various plates and shapes riveted or welded together. A form often used, the PIPE STANCHION, consists of a wrought iron or steel tube fitted with special

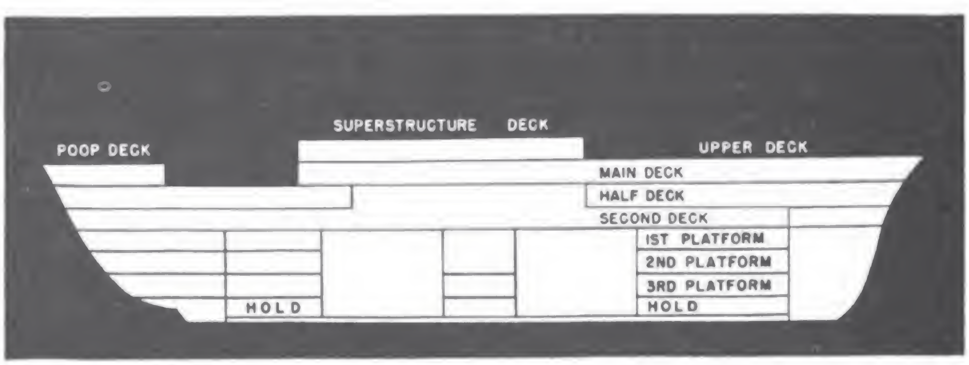


Figure 7–15.—Composite diagram showing the relationships of decks.

pieces for securing it to the deck beams at its upper end, or head, and lower end, or heel.

A BULKHEAD is a vertical partition extending athwartship or fore-and-aft of a vessel. A bulkhead may be watertight, oiltight, airtight, or nonwatertight. Watertight bulkheads subdivide the internal space of a ship into a number of compartments which contribute to the safety of the ship and afford proper utilization of space. Bulkheads must be sufficiently strong to withstand the pressure of water in case of severe flooding. As a part of a ship's structure, bulkheads act as rigid diaphragms and webs, resisting certain compressive and distorting forces. Special applications of bulkheads have led to descriptive designations such as swash bulkheads, torpedo bulkheads, etc.

Like decks, bulkheads consist of plating and reinforcing bars. In the case of bulkheads, the reinforcing bars are known as BULKHEAD STIFFENERS. Types of bulkhead stiffeners are shown in figure 7–16. The bulkhead stiffeners usually are placed in the vertical plane, and are secured at the top and bottom and to any intermediate deck by brackets attached to the deck plating. The size of the stiffeners depends upon their spacing, the height of the bulkhead, and the hydrostatic head which the bulkhead is intended to withstand.

The design of the bulkhead and the bulkhead stiffener must be such that the structure is strong enough to resist excessive bending or bulging in case of flooding in either of the compartments of which it forms a boundary. If too much deflection takes place some of the rivets or seams are liable to failure.

The STEM is a continuation of the keel, as shown in figure 7–17. In large vessels the connection of the stem to the flat keel plate was formerly made by having an independent steel casting for the lower section, which was suitably formed to the shape of the hull, and had a rabbet or channel recess cut in the lower-after edge to

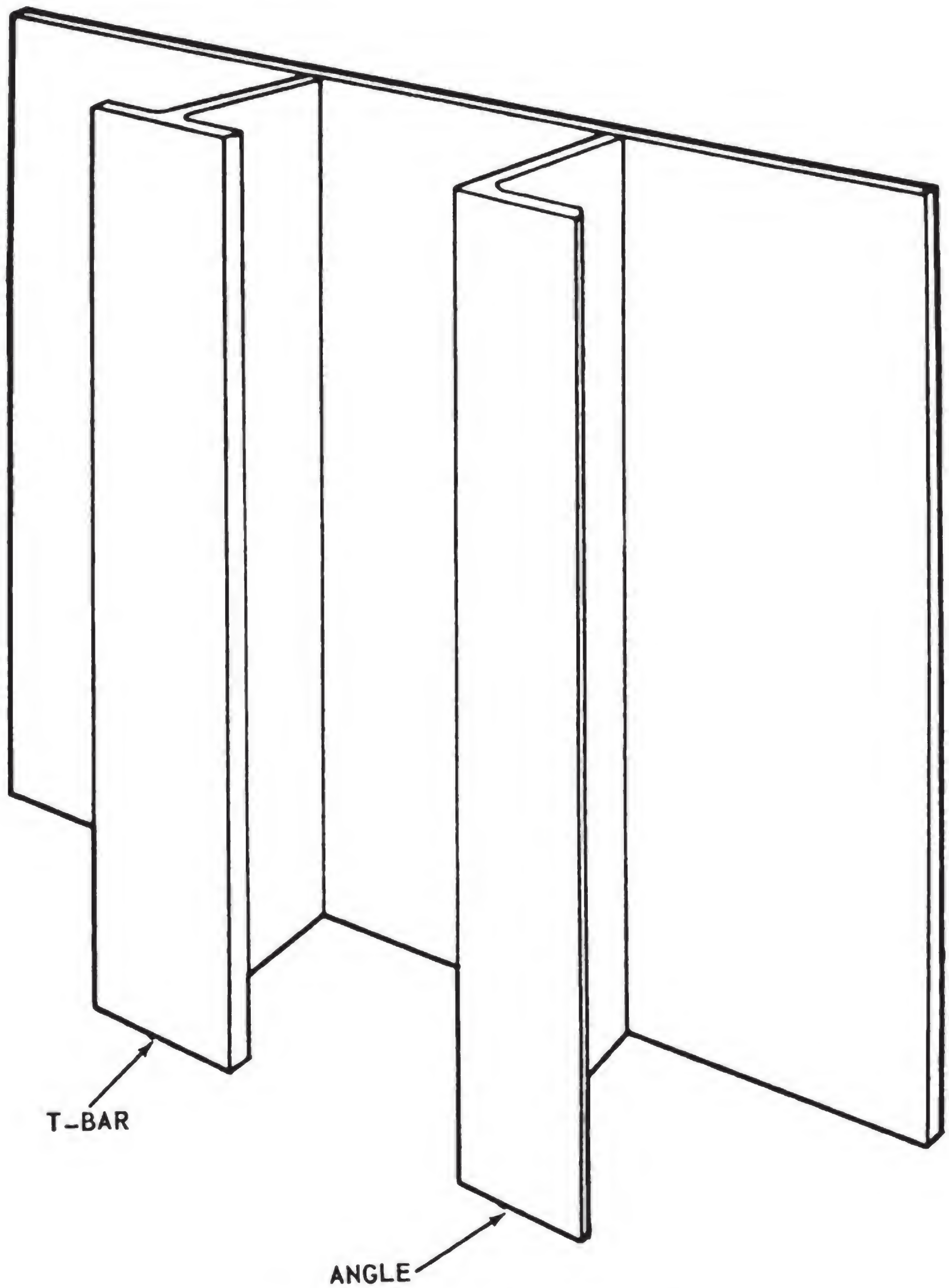


Figure 7-16.—Types of bulkhead stiffeners.

receive the flat plate keel to which it was securely riveted. The upper portion of the stem was formed by a single casting, or by a number of castings scarphed or joined by beveling each component in such a way as to form a single unit in appearance. These castings were formed with projecting webs or lugs for the attachment of decks, longitudinals, floor plates, etc. For extra strength, the shell plating was usually doubled at this point, as shown in the upper part of the stem in figure 7–17, the outer layer overlapping the inner so that a rabbet of two steps was cut in the afteredge of the stem casting. Such castings were employed on the older battleships and cruisers. On the older destroyers and other smaller ships the stem was less complicated, utilizing merely a flat bar of forged steel.

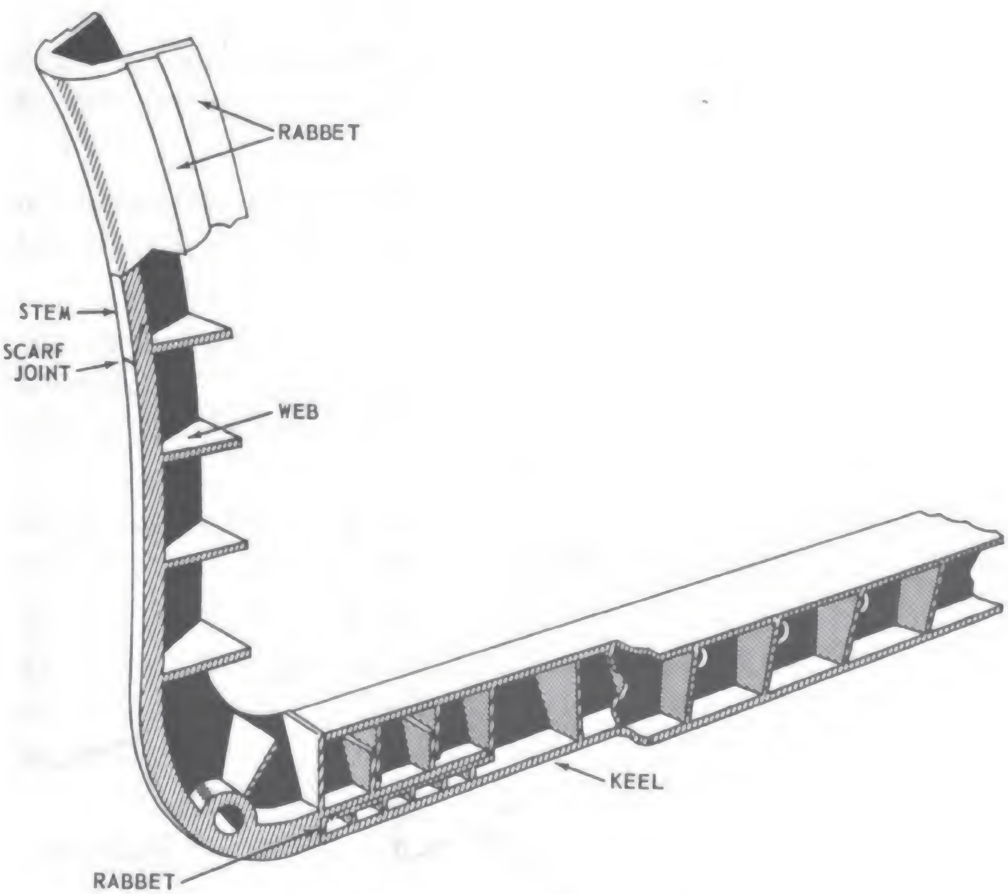


Figure 7–17.—Diagram to show relationships of keel and stem castings.

Compartmentation

Compartmentation is the subdivision of the ship by boundaries of varying degrees of tightness. The interior of the hull is divided into compartments by deck and by longitudinal and transverse bulkheads. Subdivision serves certain general purposes, as follows:

1. Adds to structural stiffness and strength of hull.
2. Forms boundaries of varying degrees of tightness for the control of flooding.
3. Segregates activities and stowage space.
4. Separates liquid storage spaces.
5. Restricts diffusion of enemy chemical warfare agents.

Watertight compartments are identified by letters and numbers. The ship consists of three principal divisions, lettered A, B, and C, from forward aft. On older ships a D division was also included. Compartments in each division are numbered beginning at the forward end of the division.

1. DIVISION A comprises all of the space between the stem and the forward transverse bulkhead of the forward machinery compartment.
2. DIVISION B comprises all of the space between the forward transverse bulkhead of the forward machinery compartment and the after transverse bulkhead of the after machinery compartment.
3. DIVISION C comprises all of the space aft of the after transverse bulkhead of the after machinery compartment.

All lettered and numbered compartments in the A division of the ship are identified by the letter A preceding the other letters and numbers. All such compartments in the B division are identified by the letter B, and all those in the C division by the letter C. (See fig. 7–18.)

The main deck is the first complete deck and compartments on it are numbered from 101 through 199. Compartments on the second complete deck are numbered

from 201 through 299; compartments on the third deck from 301 through 399; and so forth. In ships recently constructed the 900 series is reserved for the bottom compartments, and in ships with a third bottom, the 800 series is reserved for compartments between the second and third bottoms. The series from 1 to 100 is reserved for compartments which reach from the bottom past several decks toward the top of the ship. Half decks are labeled with the same series as the full deck immediately below, except that a letter H is added preceding the num-

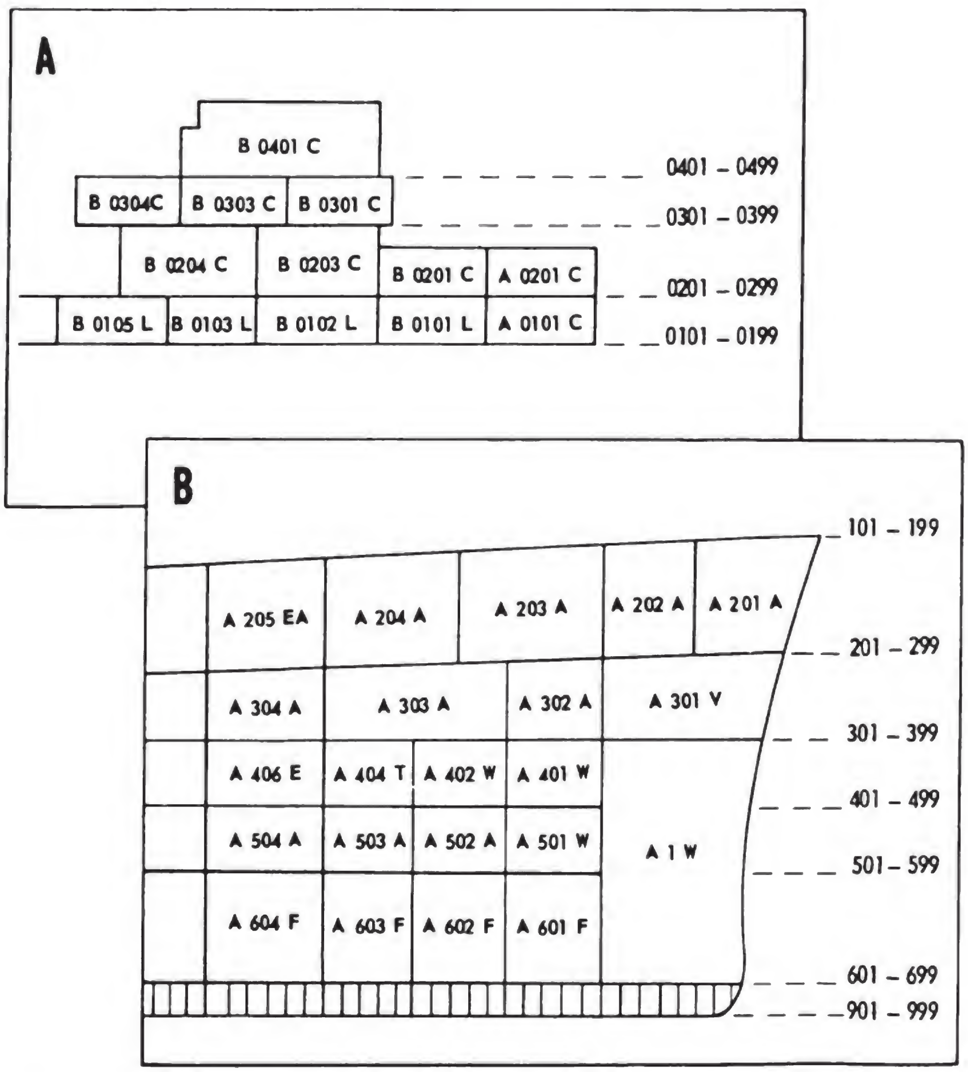


Figure 7–18.—Diagram showing compartment lettering and numbering system on a ship.

ber and following the division letter. For example, a compartment in a half deck above the second might be labeled AH–206–L. The first superstructure deck above the main deck contains compartments labeled from 0101 through 0199. Compartments in the next higher deck are labeled from 0201 through 0299, and so forth.

Each number on a deck also tells you the approximate position fore and aft. Numbering begins at the bow and proceeds aft. Odd numbers are assigned to compartments on the starboard side and even numbers to those on the port side. When a compartment extends all the way across, either an odd or an even number may be used. (See fig. 7–19.) When watertight spaces are cut into smaller spaces by air tight or fume tight bulkheads, each of these smaller spaces receives the number of the large watertight space plus an appended number, such as A–206–A and A–206–2A.

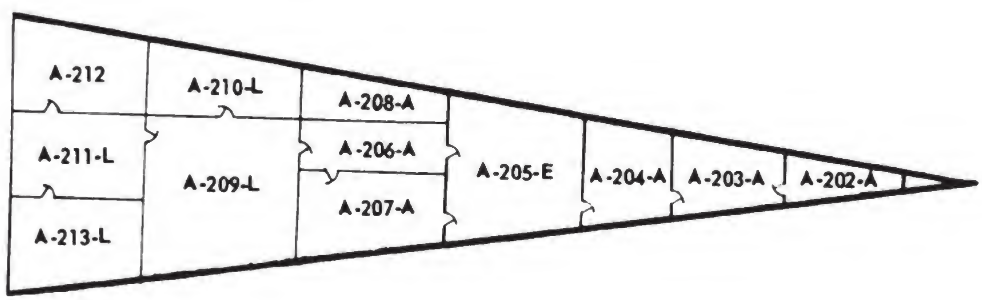


Figure 7–19.—Numbering system for a deck.

The compartment identification also includes a final letter which indicates the use for which the compartment is intended.

The letter A indicates storerooms, including band room, refrigerator compartments, storerooms proper, tool and supply rooms, and unassigned compartments usable as storerooms.

The letter B is used for battery compartments, includ-

ing secondary battery compartments, torpedo rooms, all compartments within turrets, and turret handling rooms.

The letter L is used for living compartments.

Other letters used include the following:

E for machinery	V for void
C for ship and fire control	W for water
F for fuel	LUB for lubricating oil
M for ammunition	GAS for gasoline

AERONAUTICAL STRUCTURES

When drawings are to be made for a particular airplane, the practices followed by the manufacturer of that plane serve as a guide. As a general rule, detail and assembly drawings of aeronautical structures are made actual size. This necessitates the use of drawing sheets of greater width and sometimes of great length. It is desirable, however, that the length should not exceed 144 inches. On large-sized drawings, horizontal and vertical zoning may be used as an aid to the location of items when the drawing is read. The approved method of zoning is described in MIL–STD–3A, *Format for Production Drawings.*

Large detail, assembly, and installation drawings may be drawn to a reduced scale if information can be clearly shown in all respects. In order to do this, section or partial views may be drawn actual size where necessary. Draftsmen should bear in mind that the purpose of reducing the scale of a drawing is to reduce the size of the sheet to be handled and to avoid wastage of drawing and blueprint paper and file space. Therefore, as small a sheet should be used as practicable without crowding the drawing. Enough space should be left so that sectional views, notes, or tabulations can be added if these become necessary during the life of the drawing.

It is customary for every airplane part to have a number which corresponds with its detail drawing number. If more than one part is shown on one detail draw-

ing, further identification may be accomplished by DASH NUMBERS. Thus, two parts shown on a single drawing may be numbered 34105–1 and and 34105–2. On the drawing, the dash number preceded by the dash should be placed in a small circle near the part it identifies. An arrow drawn from the circle should touch the outline of the part.

Sometimes, dash numbers are also used to distinguish between right hand and left hand parts which are mirror images of each other. In this case, the left hand part may be shown and the right hand part indicated by a note.

Drawing titles are given with identification first and description second. For example, the title FLANGE-CARBURETOR AIR INTAKE would be read, CARBURETOR AIR INTAKE FLANGE.

Only as many views should be drawn in third-angle orthographic projection as are needed to clearly illustrate the part to be made. It is customary for principal views to be taken from the left side of the airplane with the nose pointed toward the left border of the drawing sheet. Partial views and sections may be used to illustrate certain features, thus making a greater number of complete views unnecessary.

One view may be used, for example, in drawing a stud if the diameters are clearly marked as diameters. One view of a detail should correspond to the position of the view as shown on its next assembly drawing whenever possible. However, a part which is shown in an angular position when it is assembled should not be drawn in an angular position as a detail.

Sections should be projected directly if space permits, but if it is limited, a section view may be placed elsewhere on the sheet or on a separate sheet. Views which are not projected directly should be clearly marked to indicate the location from which they were taken and the direction in which they are viewed.

Various systems of station marking are used on aircraft drawings. For example, the centerline of the air-

plane on one drawing may be taken as the zero station, and objects to the right or left of center along the wings or stabilizers may then be located by giving the number of inches between them and the centerline zero station. On other drawings, the zero station may be at the nose of the fuselage, at a firewall, at the leading edge of a wing, or at some other location, depending on the purpose of the drawing and the custom concerning the particular part or assembly. (See fig. 7–20.)

Isometric, perspective, or photographic views may be employed under some conditions where one of these types of drawing more clearly depict the article than the conventional orthographic projection. These drawings are of particular advantage when it is necessary to illustrate the installation of plumbing, wiring, or control linkage. However, with the curving lines and lack of parallelism, aircraft drawing is not considered easy even in orthographic projection, and the problem can be greatly magnified when an attempt is made to work in three dimensions. When three-dimensional drawings must be made, time can be saved and the work made easier if portions of new drawings, especially outlines, can be traced from other drawings and the appropriate additions drawn in. (See fig. 7–21.) A file of isometric outline drawings may be kept in the drafting room for this purpose.

Dimensions

Because of the large size of many drawings, dimensions should be made to read from the bottom. Dimensions are usually given in inches although some over-all dimensions, such as wing span, are sometimes given in feet. In many activities, it is preferred that all dimensions be given in decimals instead of in common fractions.

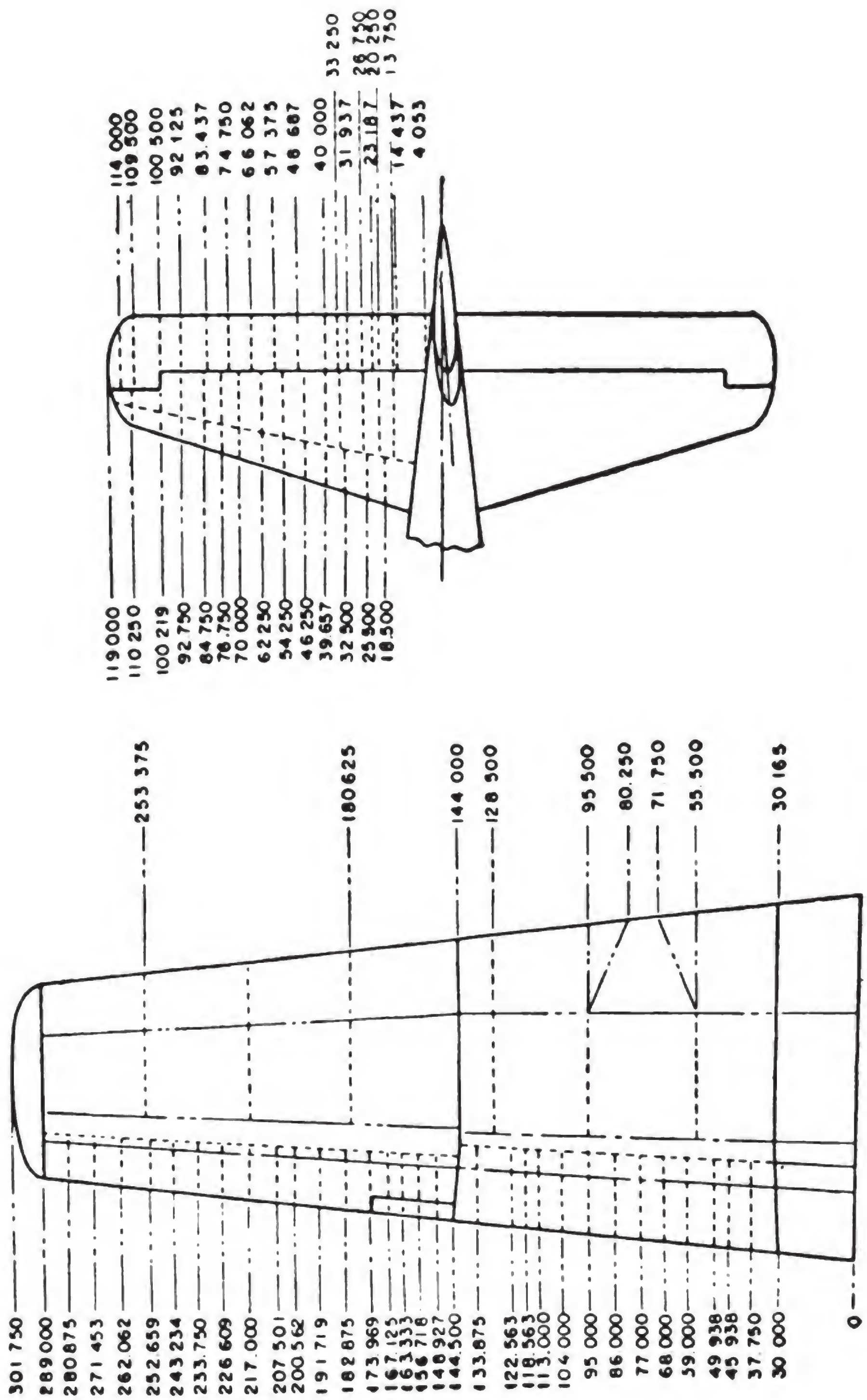


Figure 7–20.—Station marking.

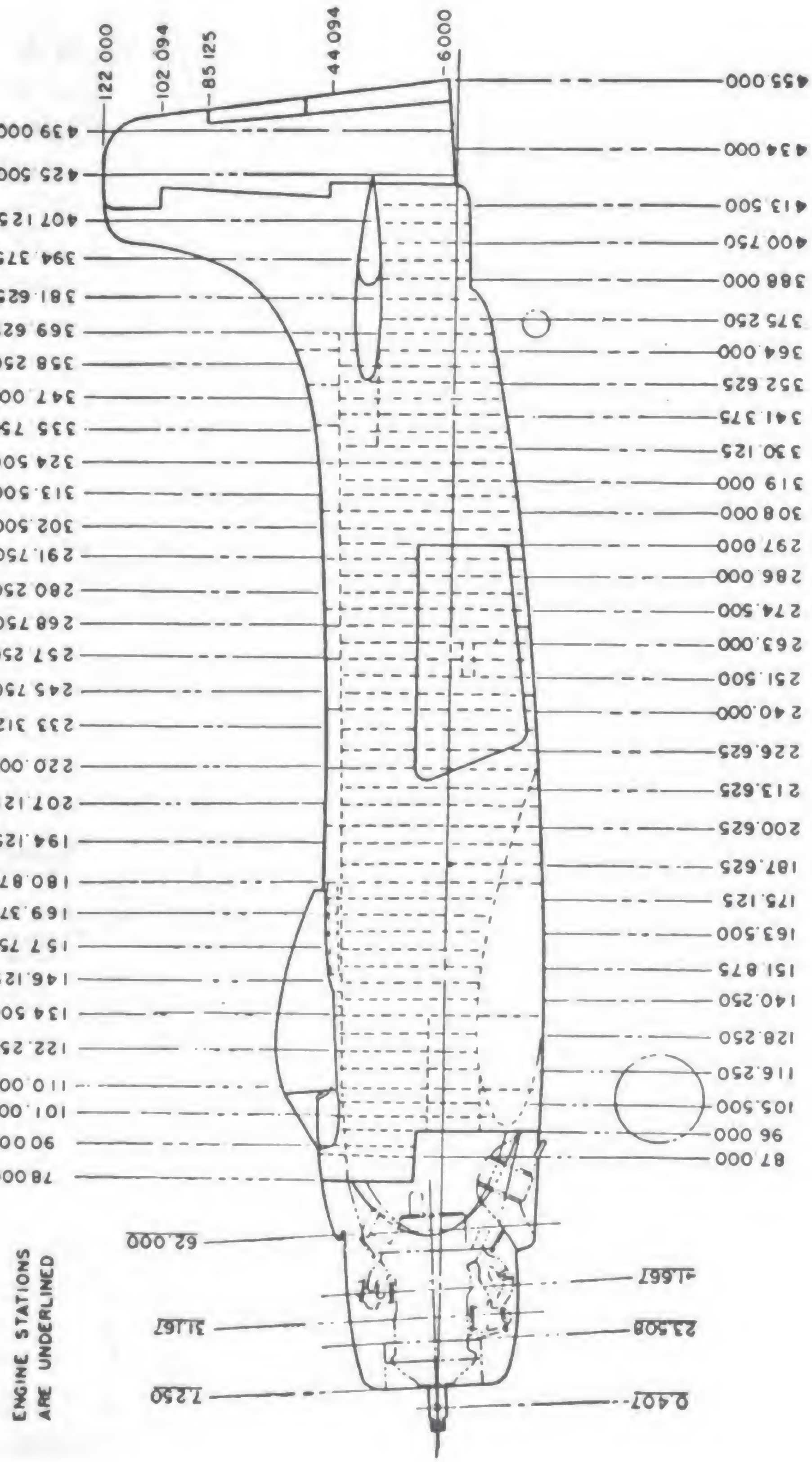


Figure 7-20.—Station marking—continued.

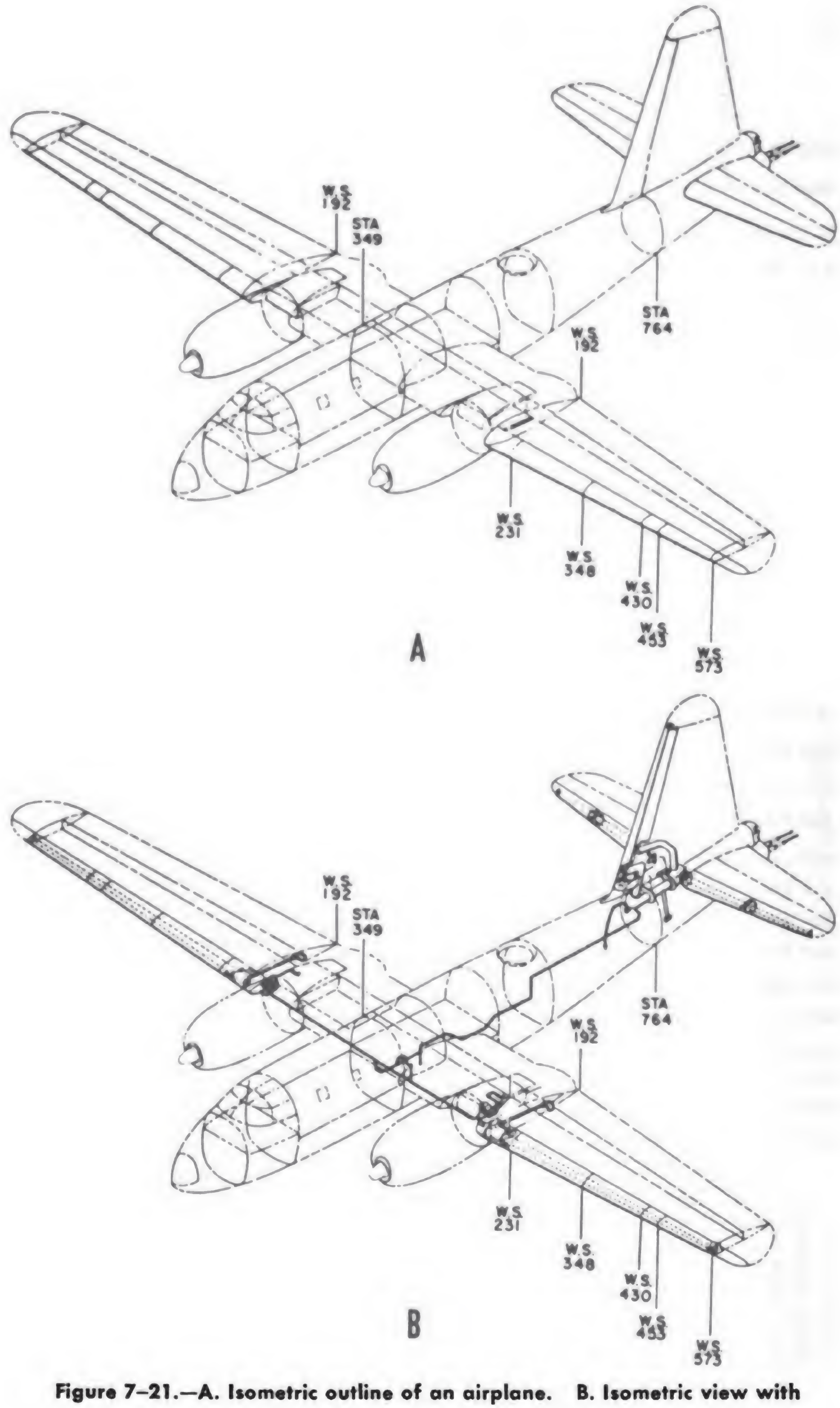


Figure 7–21.—A. Isometric outline of an airplane. B. Isometric view with de-icing system added.

Airplane Structure

A study of figure 7–22 will serve to refresh your memory with the names of the important parts of a typical airplane. The main structural unit is the fuselage, and other units are attached directly or indirectly to it. There are basically two types, or principles, of construction which are applied to aircraft, as well as some modifications or combinations of the two. These are the TRUSS type of construction and the MONOCOQUE type.

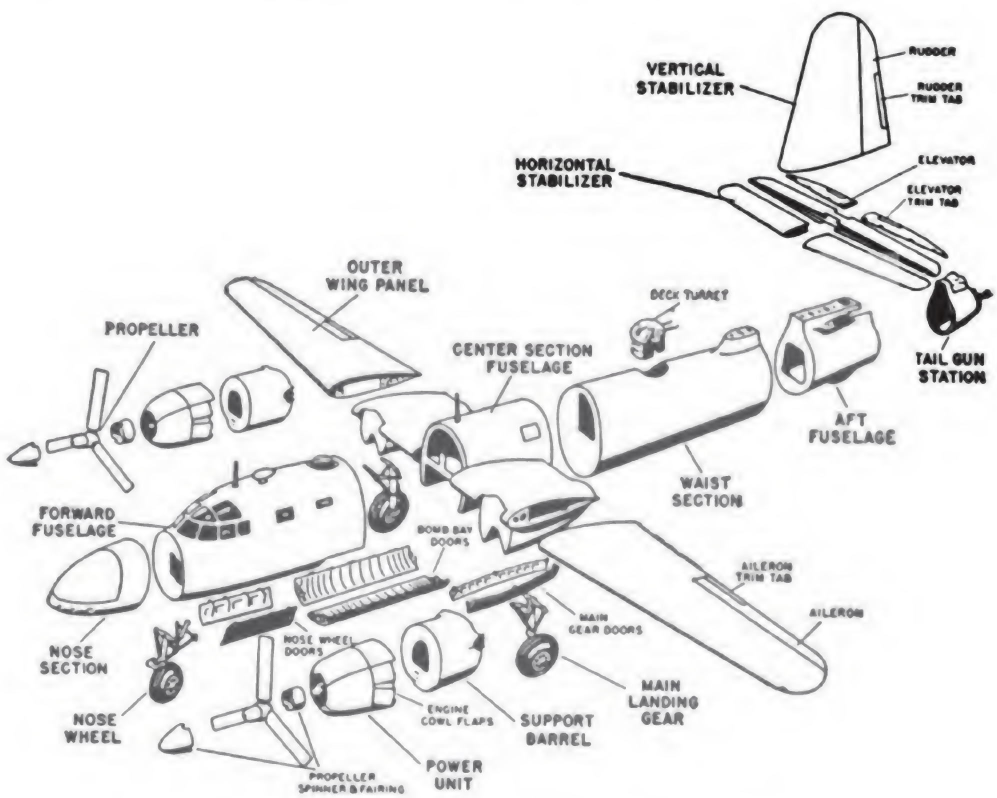


Figure 7–22.—Nomenclature of aircraft structures.

In the truss type of construction, metal tubing or wood is joined in a series of triangles or trusses similar to the trusses of a building frame or bridge construction. (See fig. 7–23.) This framework is covered with cloth which later is saturated with a liquid called DOPE. When it hardens, dope greatly increases the strength and tautness of the cloth and also makes it impermeable to air

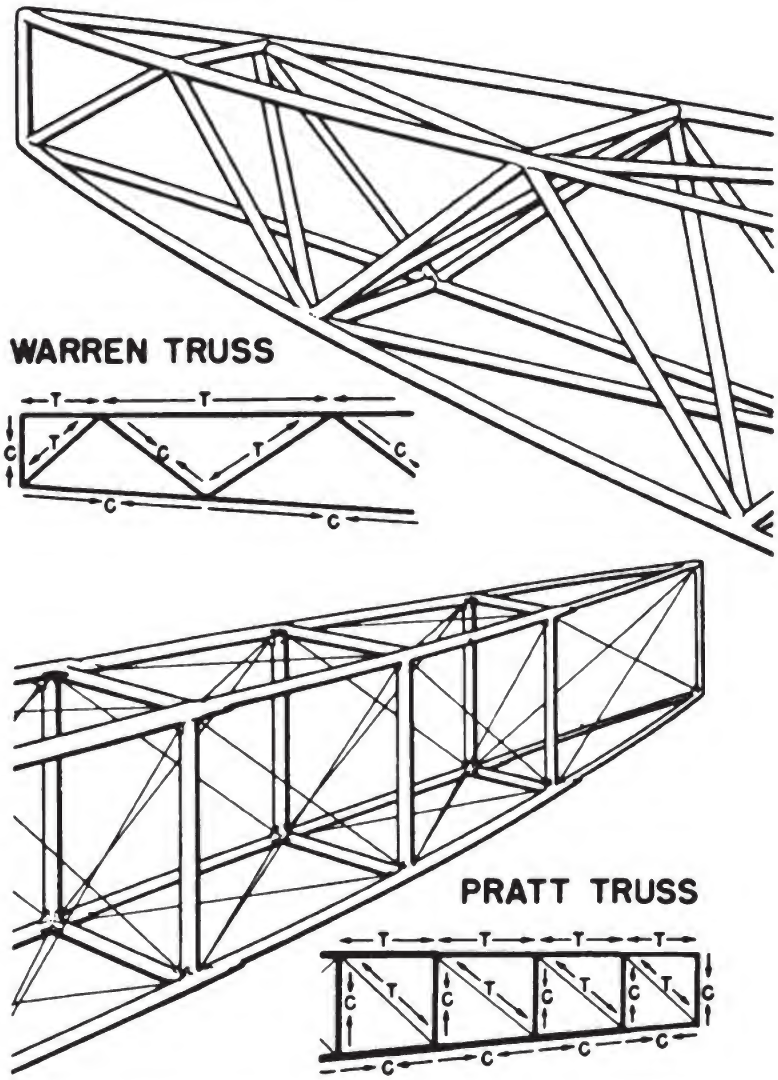


Figure 7–23.—Truss type fuselage construction.

and water. Most of the structural strength, however, is considered as coming from the framework and not from the covering. Today this type of construction is rarely used except on small aircraft or on parts for larger planes.

The monocoque type of fuselage relies largely on the metallic skin or shell for strength and rigidity. (See fig. 7–24.) The skin is reinforced and held in correct form by vertical rings, formers, and bulkheads.

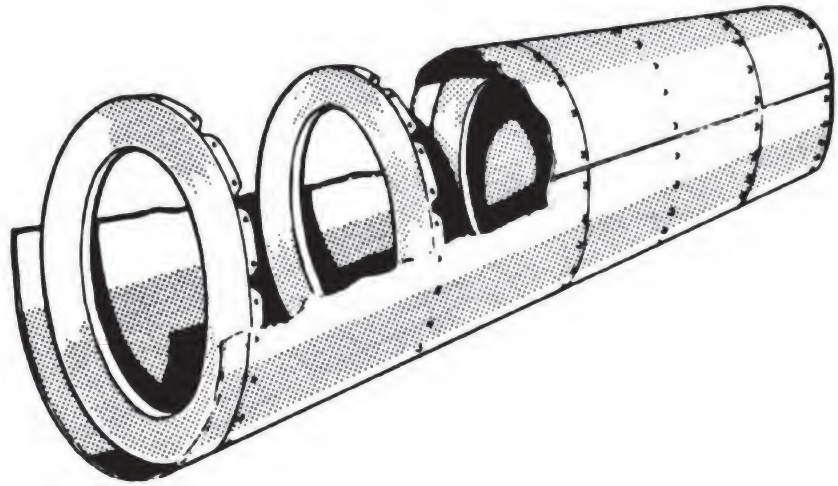


Figure 7–24.—Monocoque fuselage.

Most military aircraft have what is known as semimonocoque construction. In this type, part of the stress is borne by the shell and part by lengthwise members, called stringers. (See fig. 7–25.)

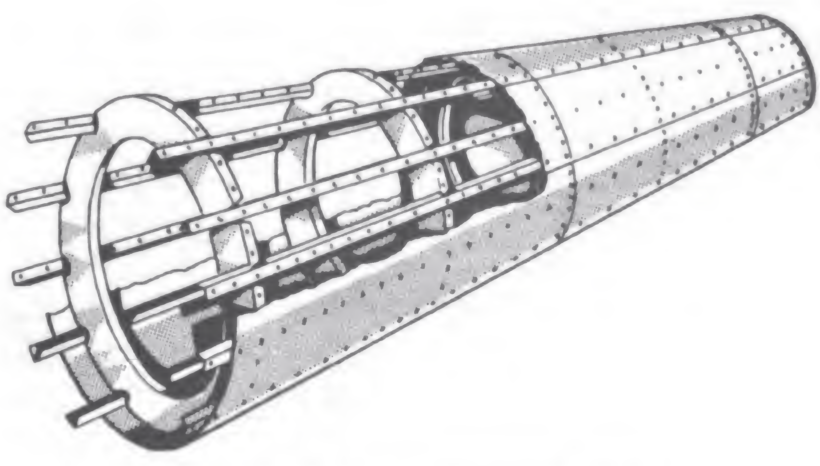


Figure 7–25.—Semimonocoque fuselage.

A typical wing structure is shown in figure 7–26. Control surfaces, such as ailerons, elevators, and rudders, have structures similar to wings.

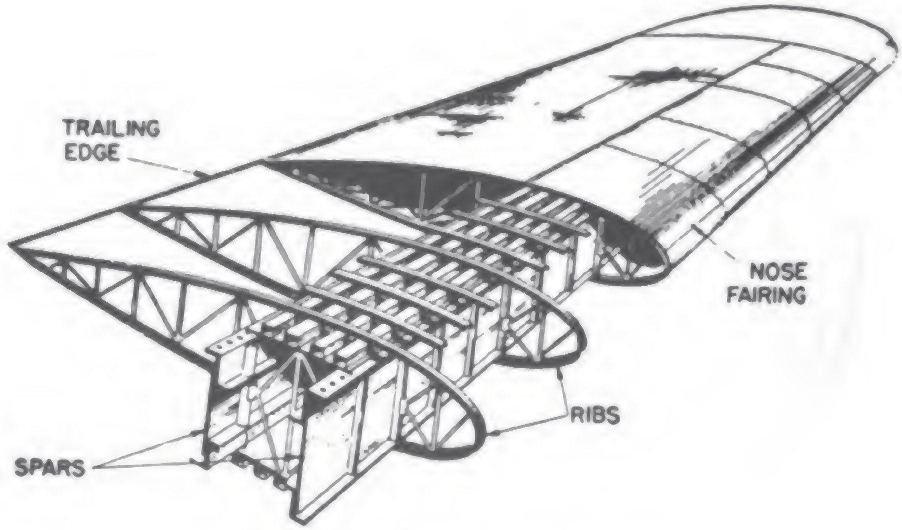


Figure 7–26.—Typical wing structure.

Figure 7–27 illustrates two types of engine mount. Although engine mounts vary greatly in appearance, depending on the size, type, and characteristics of the engine, the basic structural features are similar. Among the things which must be considered in the design are the thrust and torque of the propeller, the weight of

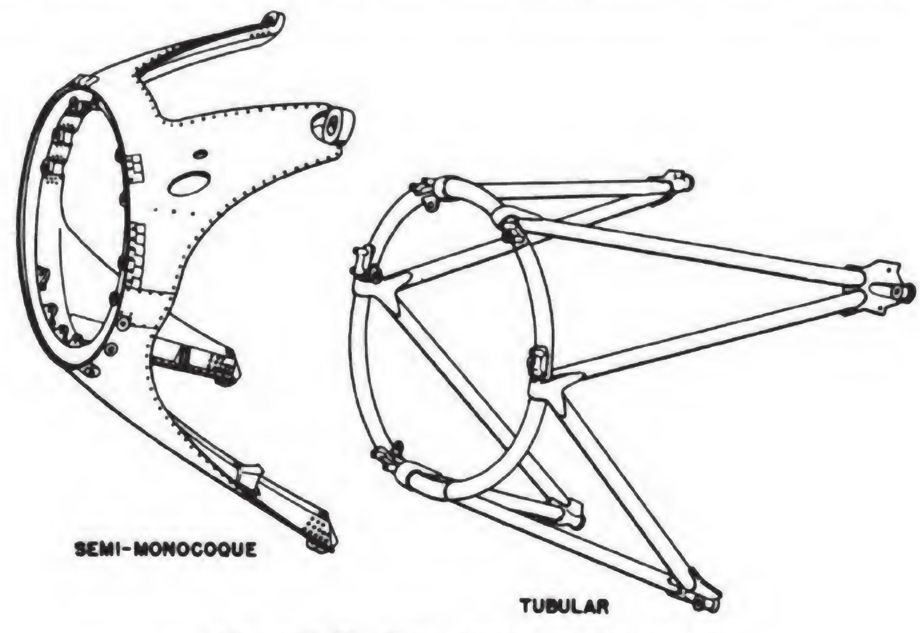


Figure 7–27.—Two types of engine mount.

the engine and the vibration. Also, the engine and its equipment must be accessible for maintenance and inspection. Engine mounts are always placed just forward of a flame-tight bulkhead, called a firewall.

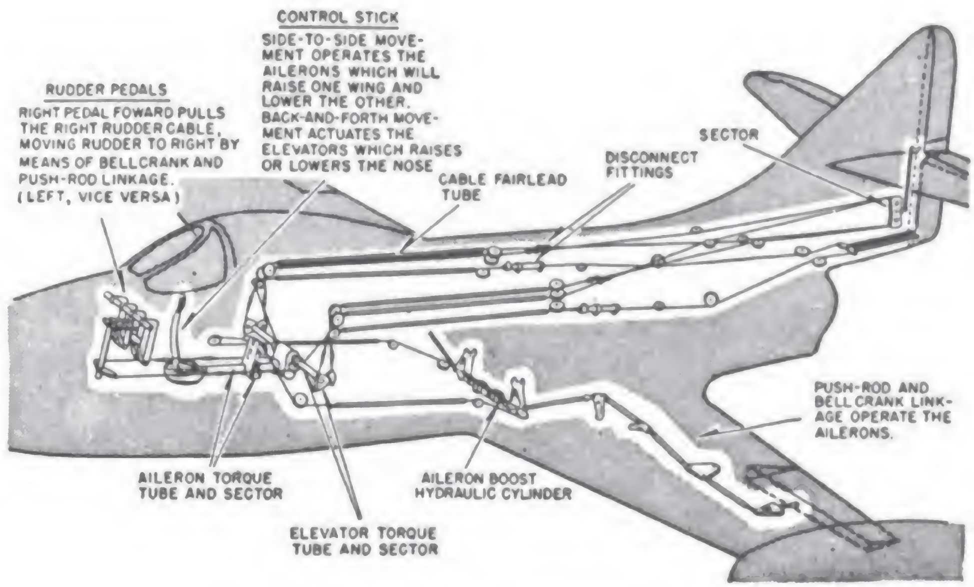


Figure 7–28.—Typical control system diagram.

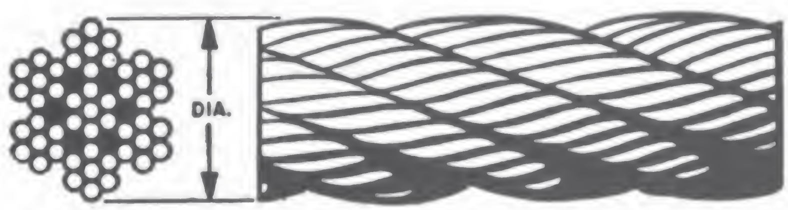


Figure 7–29.—Control cable.

A typical control system is illustrated in figure 7–28. The cables, rods, bell cranks, etc., which connect the controls to the control surfaces, are called the flight control linkage. Figures 7–29 and 7–30 illustrate types of cable, cable terminals, and cable fittings.

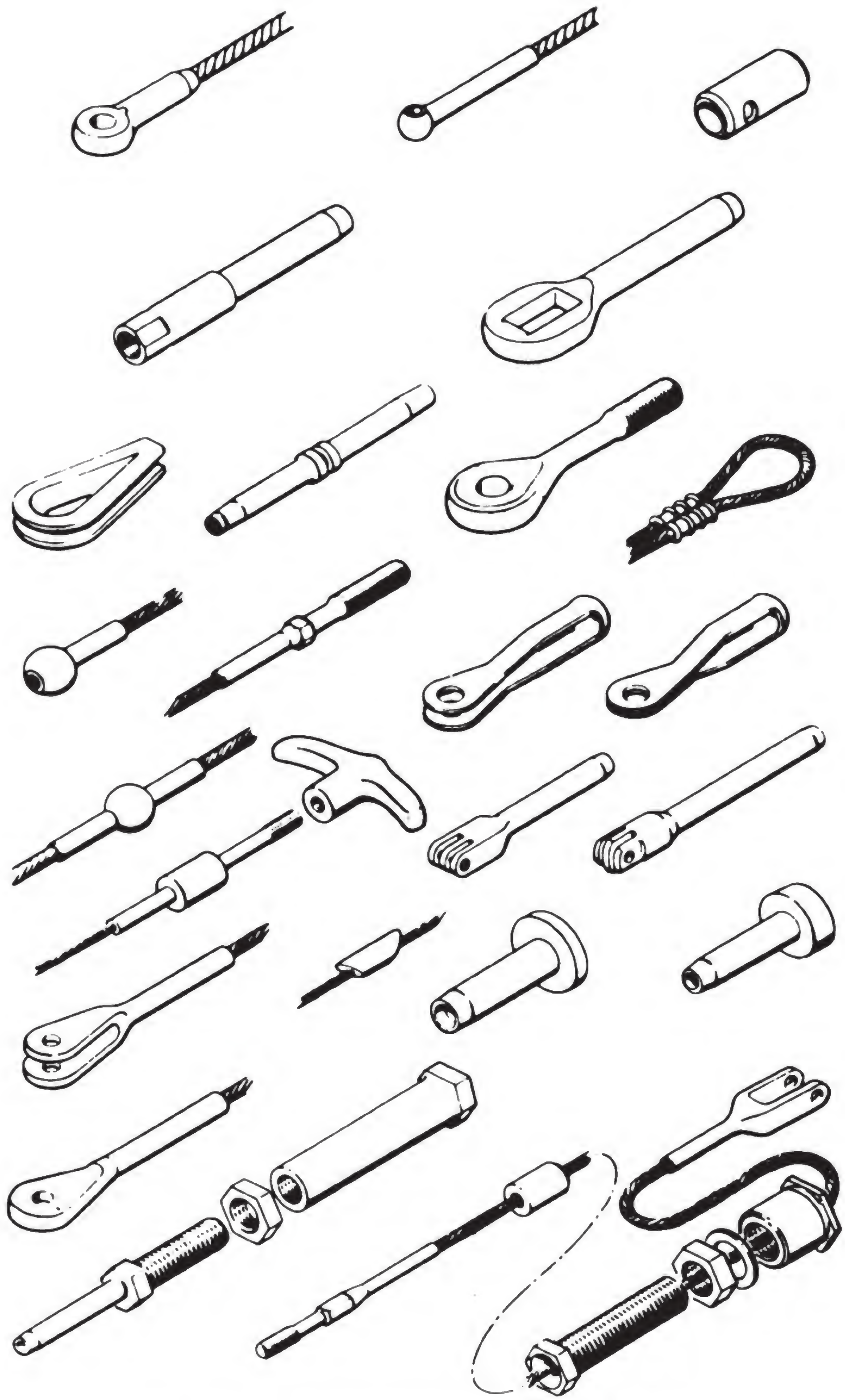


Figure 7-30.—Cable fittings and swaged terminals.

Most airplanes, with the exception of small, slow planes, have retractable landing gear. The wheels may be retracted toward the rear, inward toward the fuselage, or outward toward the wing tips. Retracting may be accomplished manually, electrically, or hydraulically. Usually, electrically or hydraulically operated units have manual controls for emergency use.

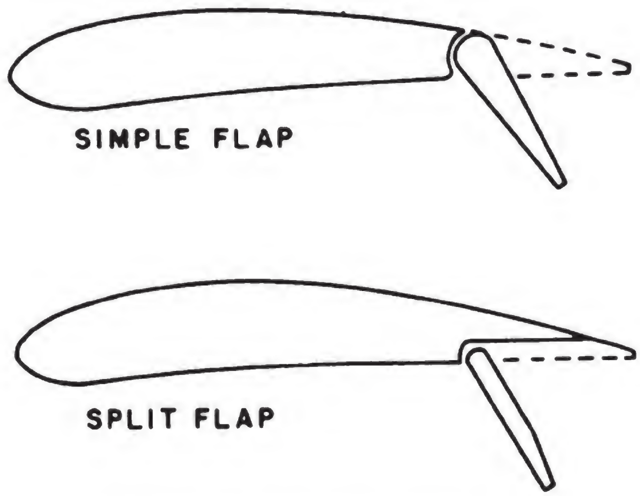


Figure 7–31.—Two basic types of flaps.

Relatively large airfoils hinged to the trailing edge of the wings near the fuselage are called wing flaps. (See fig. 7–31.) When they are lowered, they increase both the lift and the drag of the wings. This enables the pilot to reduce the airspeed when the plane is descending and to approach a runway at a steeper angle than would otherwise be possible. This steeper descent results in a shorter landing roll. The flaps can also be used to give extra lift to the wings when the plane is taking off.

QUIZ

1. What are record drawings?
2. If a preliminary drawing is to be used as a basis for bids for contracts, how complete should it be?

3. What is the first step in making an estimation of the materials needed for a construction job?
4. Why is it important to list the materials in terms of the customary units?
5. In terms of what unit is steel for floating structures listed?
6. What is a board foot?
7. In terms of what units is concrete measured?
8. How are the proportions of a concrete mix usually expressed?
9. What is a square of roofing?
10. What types of airfield drawings may be required?
11. Where is the imaginary plane called the BASE LINE PLANE located on the ship?
12. What are waterlines?
13. (a) What are the buttock planes? (b) How are the buttock lines formed?
14. What are the frame lines?
15. Name the three plans used to show the complete shape of a ship.
16. What is the designer's waterline?
17. When is a ship said to have been designed with a drag?
18. What is camber?
19. What are the rows of fore-and-aft plating which make up the shell of a warship called?
20. Name the three parts of the built-up girder called the *keel.*
21. Tell where the following compartments would be located in a ship and their use: (a) AH–206–L. (b) A–206–2A. (c) B–3–2E.
22. From which direction is it customary for principal views to be taken in aeronautical drawings of airplanes?
23. What are the two basic types of construction which are applied to aircraft?
24. What are the cables, rods, bell cranks, etc., which connect the controls to the control surfaces called?
25. What purposes do the flaps serve?

CHAPTER 8

ELECTRICAL DRAFTING

INTRODUCTION

Most electrical drawings are schematics or diagrams. Even layouts for power distribution systems are schematics, rather than the machine type of layout requiring the utmost precision of drawing. However, since the length of cables must be estimated from electrical layouts and plans, the dimensions should be very accurate, and circuits and devices should be clearly indicated.

A good general handbook will be of value in reviewing electrical theory, including Ohm's law and other formulas for finding electrical values of circuits. Many excellent commercial publications in the field of electricity are available. Among the most useful to a DME drawing electrical layouts is the *National Electric Code Handbook,* published by the McGraw-Hill Book Company, Inc., New York, N. Y.

POWER DISTRIBUTION SYSTEMS

Electricity is of value as a source of power chiefly because it can be distributed with relative ease over great distances. You may have occasion to make layouts of DC distribution systems, as well as AC systems, but most landbased systems are AC. Alternating current is better than direct current for use where power is to be transferred over long distances, because transformers can be

used in AC systems to change the ratio between voltage and current. With a high voltage and a low current in the circuit, smaller wires can be used, and there is less heat loss. At the equipment end, a transformer can again be used to alter the ratio between current and voltage, stepping the voltage down to some ratio at which the equipment will function efficiently.

Advanced Base Layouts

Each AC distribution system consists of a central power station containing one or more alternators, feeders, a distribution center, primary mains, and secondary mains. The system may be three-wire or four-wire de-

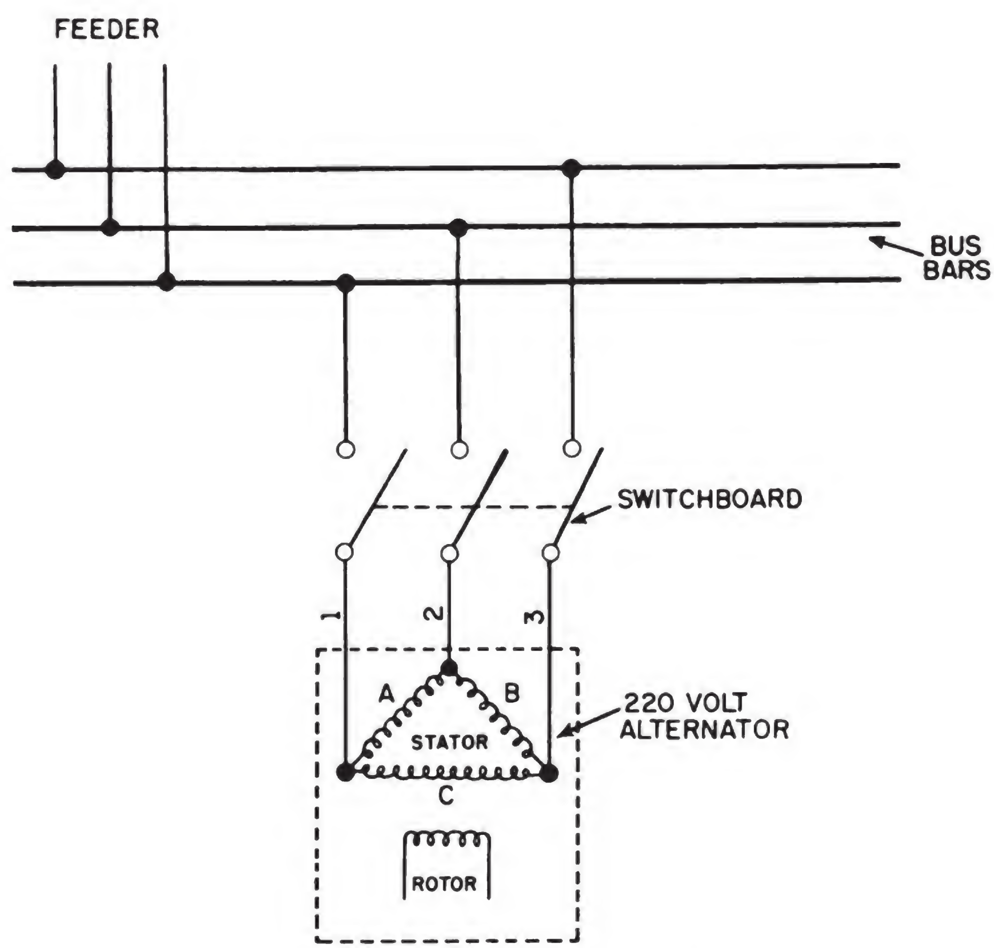


Figure 8–1.—Delta–connected alternator.

pending on whether the alternators are connected delta (Δ) or wye (Y). Schematics of these connections are shown in figures 8–1 and 8–2. With both types of connections, the alternators have three stator coils set 120 electrical degrees apart on the stator core. The output

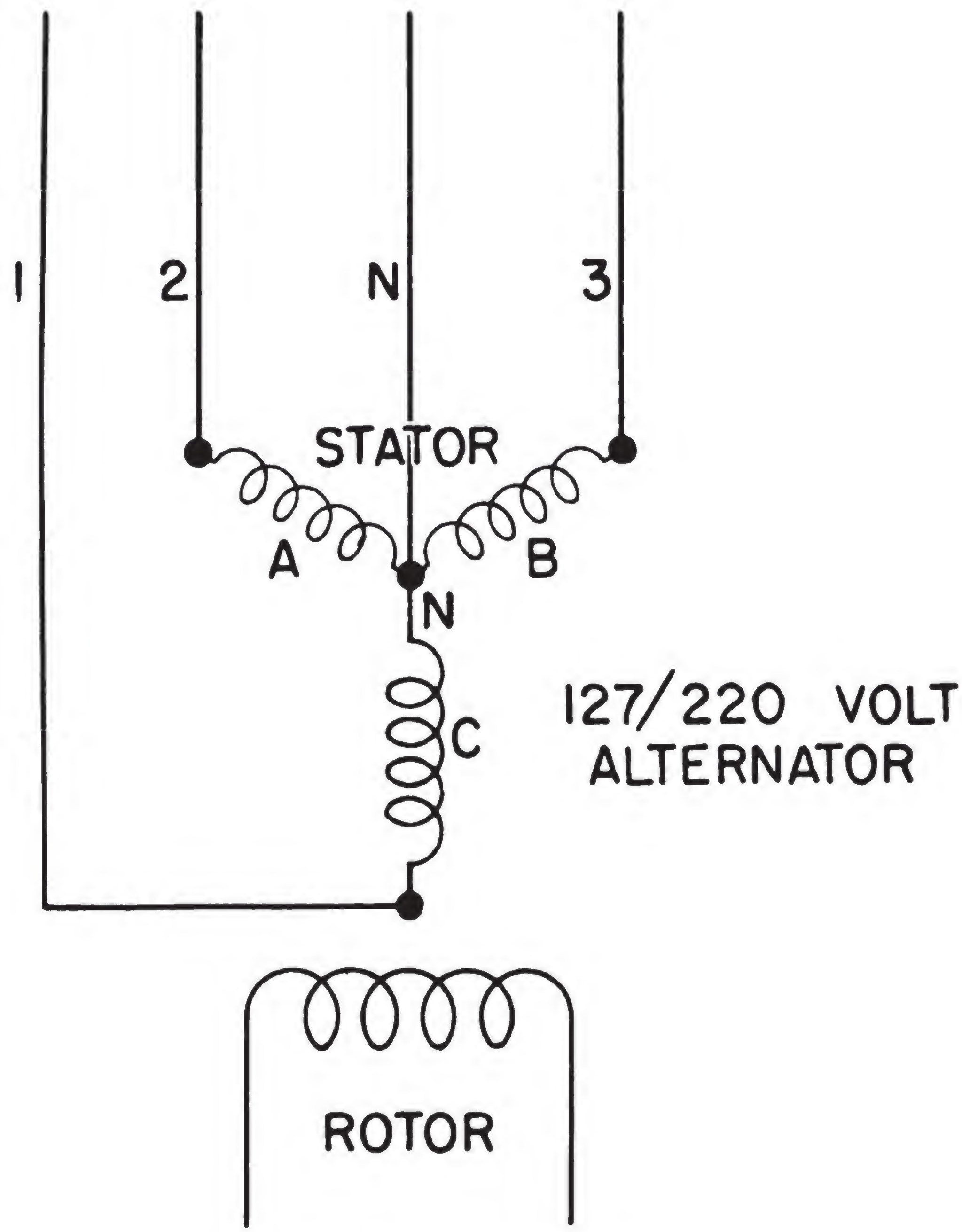


Figure 8–2.—Y-connected alternator.

of these coils is connected, through the switchboard and bus bar, to the feeder lines.

In a delta-connected alternator, any two of three lines are directly across the ends of one of the three coils. A voltmeter reading between lines 1 and 2 would show the single-phase voltage developed in coil A. Thus, if the alternator-rated voltage was 220 volts, you would read 220 volts on the voltmeter. The voltage across lines 2 and 3 and lines 1 and 3 would also be 220 volts. Each of these is a single-phase voltage, but a three-phase voltage can be obtained by taking the output from all three leads at the same time.

In a Y-connected alternator, one end of each coil is connected to a common or neutral point. The line wires are tied to the free ends of the coils. A fourth wire, called the neutral wire, is connected to the neutral point. This means that the voltage between lines 1 and 2 is the vector sum of the voltages developed in coils A and C. The same thing applies to lines 2 and 3 and 1 and 3. The voltage between the neutral wire and any one of the three leads is equal to the voltage developed in any one stator coil. A voltmeter placed between line 2 and the neutral wire, for example, would indicate the voltage developed in coil A.

Alternators which are Y-connected have two voltage ratings. For example, the alternator of figure 8–2 has a voltage rating of 127/220. Each stator coil will develop a single-phase voltage of 127 volts. The 220-volt rating indicates the voltage developed across any two of the three stator coils.

Figure 8–3 shows a pictorial view of a three-wire system, and figure 8–4 shows a wiring diagram of the same three-wire system. This particular system is a three-wire 220-volt three phase setup. Starting from the generating station, the three-wire feeder is carried overhead to the distribution center. At the distribution center, the feeder splits into two primary mains. One primary

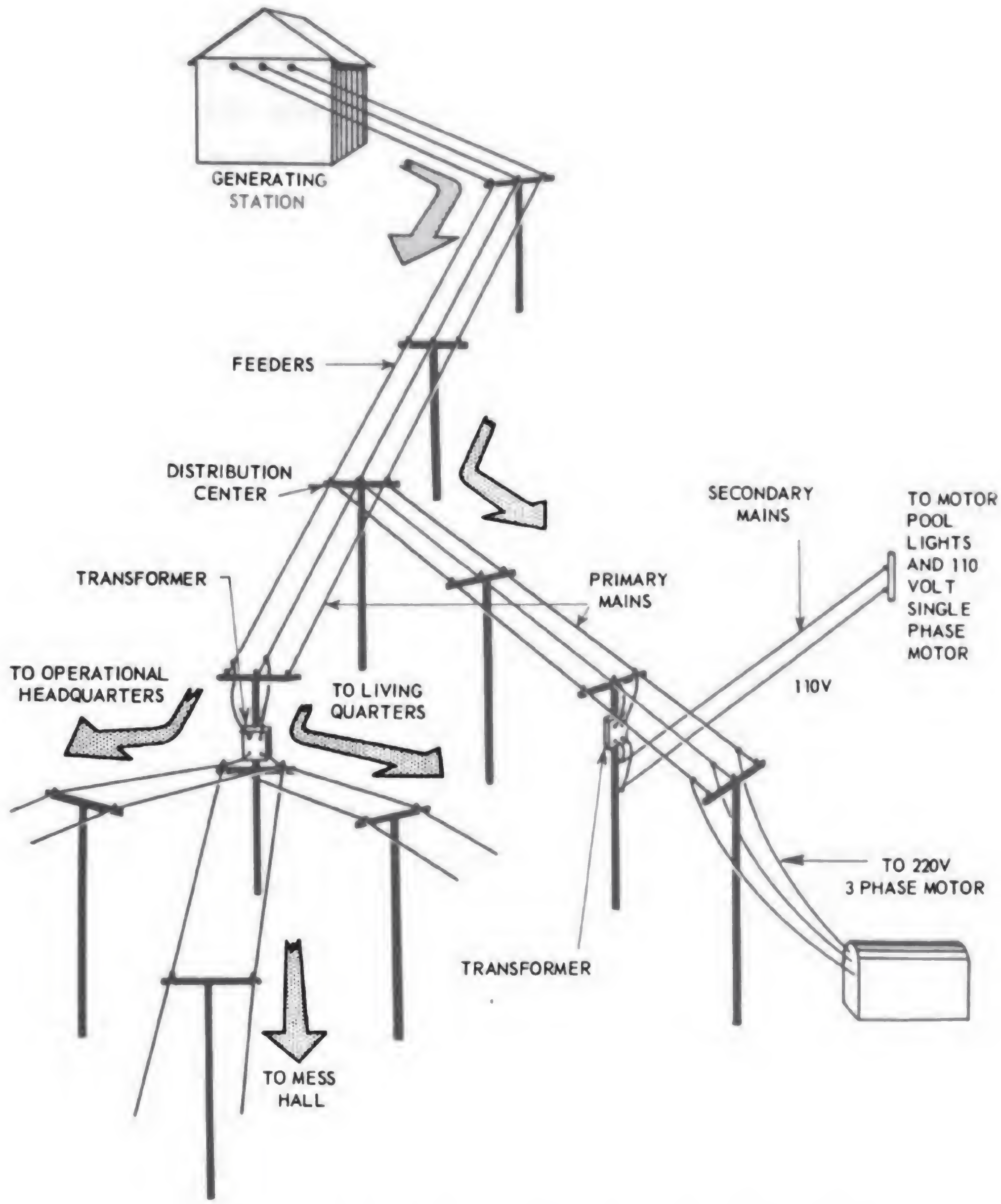
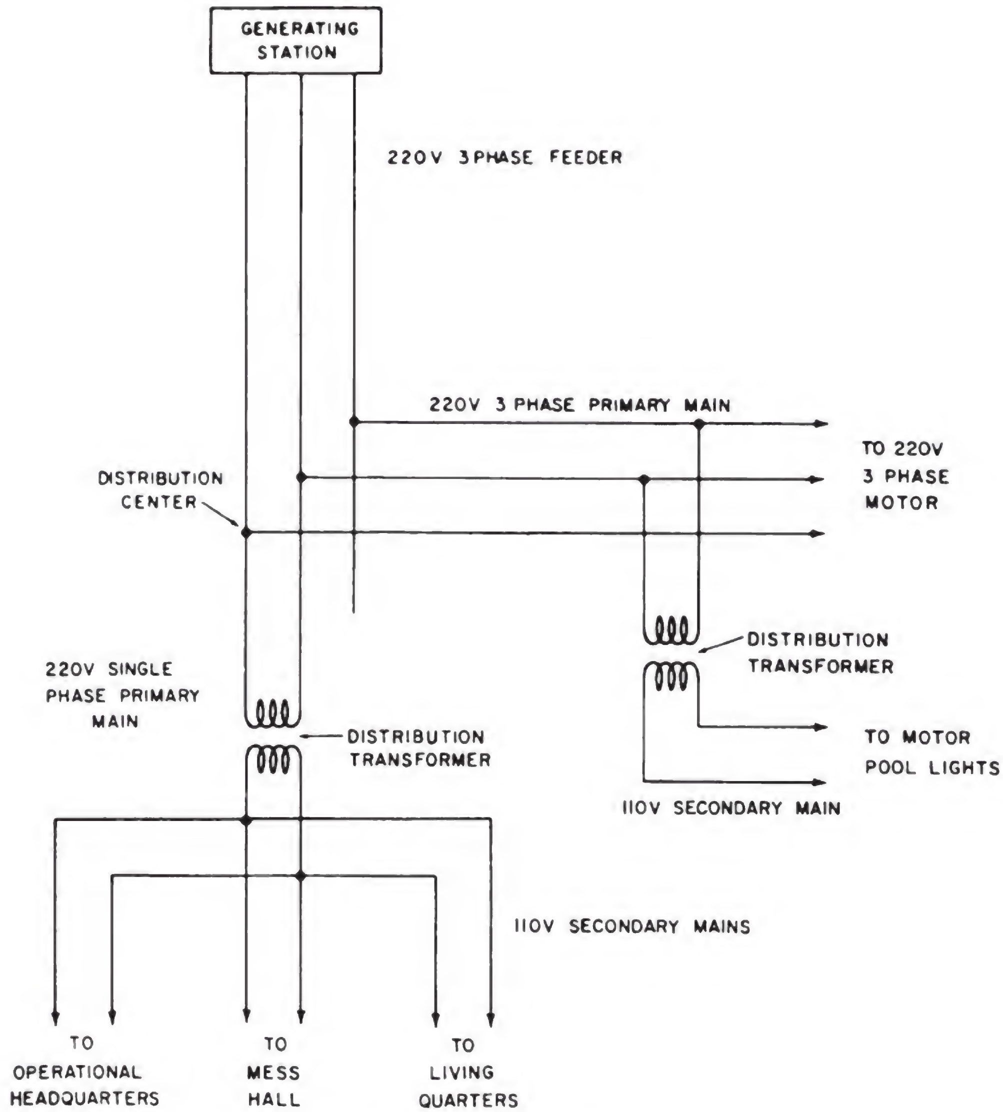


Figure 8–3.—Pictorial view of a three-wire distribution system.

main swings off to the right, the other continues toward the center section of the area.

The motor pool primary main is strung over to a pole on which a distribution transformer is hung. The primary of the transformer is connected, through fuses, to two of the feeder lines. This brings single-phase, 220-volts into the distribution-transformer primary. The distribu-



tion transformer steps the 220 volts down to 110 volts on the secondary.

The transformer secondary is connected to the secondary main. The secondary main is strung underneath the primary main. Lines are then tapped off the secondary main to any motor pool buildings which need 110 volts for lights or single-phase motors.

There's a 220-volt, three-phase motor in one of the motor pool repair shops. Power for this motor is ob-

tained by tapping directly into the 220 volt, three-phase primary main.

Notice that the primary main which feeds the central section is made up of only two of the three main feeder wires. This indicates that there is no equipment in the central section that operates on three-phase power. The transformer reduces the primary voltage to 110 volts for the secondary mains. The secondary mains distribute the 110 volts to the lights in the living quarters, the lights and refrigerator unit in the mess hall, and the lights and equipment in the operational headquarters.

Figure 8–5 shows a four-wire distribution system, and

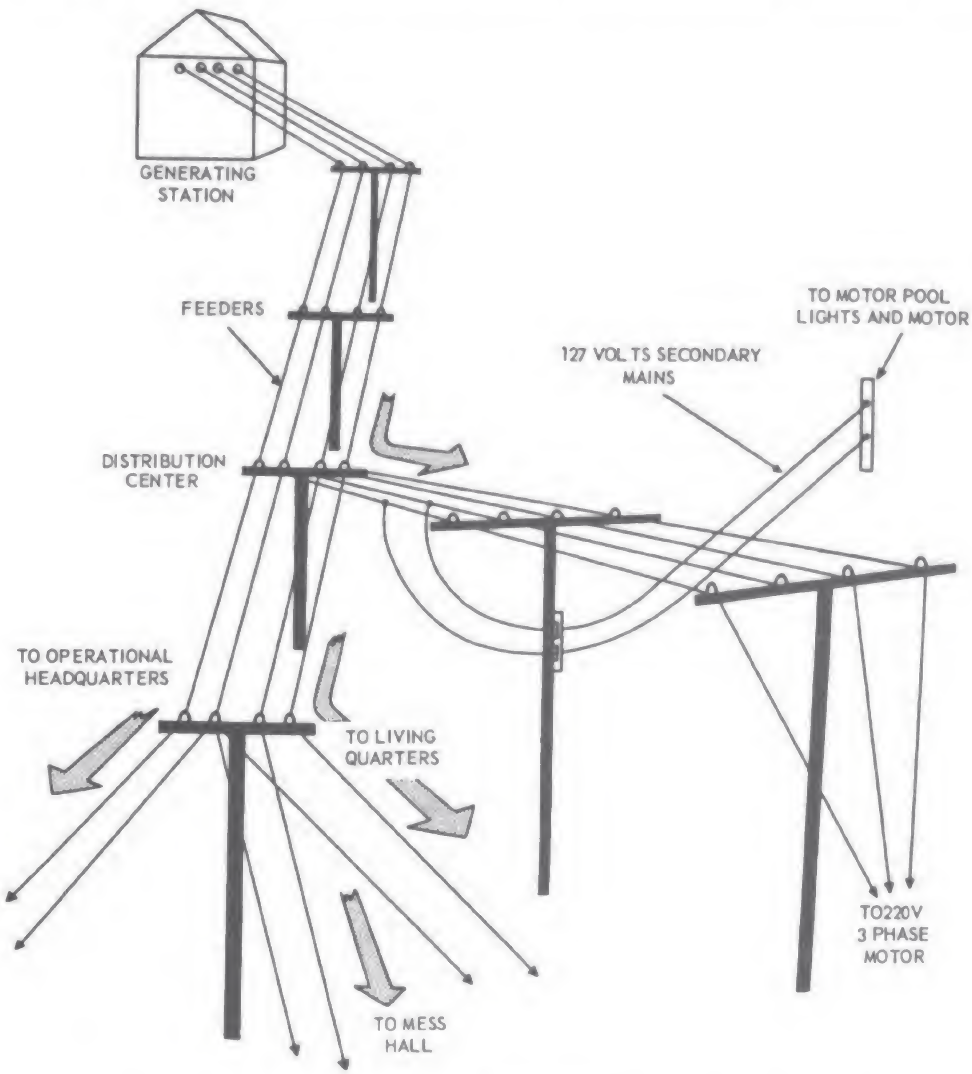


Figure 8–5.—Pictorial view of a four-wire distribution system.

figure 8–6 is the wiring diagram for the same system. The alternator in the generator station is Y-connected and rated at 127/220 volts. The four-wire feeder is strung overhead to the distribution center. Here the feeder splits into a four-wire primary main which travels over to the motor pool section, and a four-wire primary which is sent to the central section.

Since there are 127 volts single phase between the

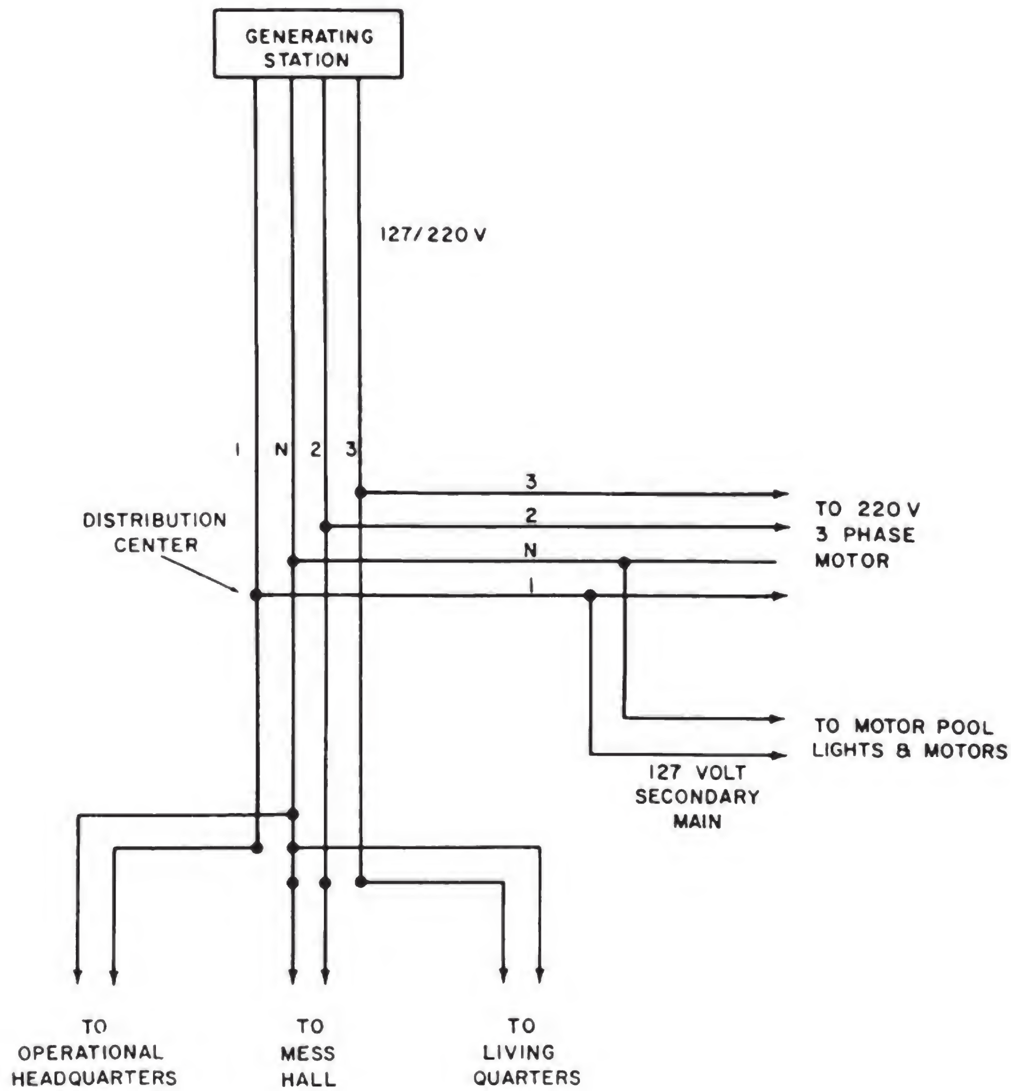


Figure 8–6.—Wiring diagram of a four-wire system.

neutral and line, it won't be necessary to use distribution transformers. Lights and single-phase motors are supplied directly from the primary main. The load on the primary main is evenly distributed by using the neutral wire and alternate lines. The three-phase motor is supplied with power from the three main wires.

BuDocks prepares standard drawings for shore installations or supervises their preparation by contractors, but it is often necessary to adapt these drawings to the particular conditions existing in the field. Suppose you are assigned to make a layout for use in wiring a section of an advanced base. You will be able to obtain a plot plan of the area including all construction planned or accomplished. You will also be given a sketch or specifications for the proposed layout. Your job will be to make drawings which a Construction Electrician's Mate can use when he is assigned to do the actual wiring.

The section of the plot plan in figure 8–7A shows five newly constructed quonsets, 40 by 100 feet, which must be supplied with electricity for both power and lighting. The dotted line across the bottom of the drawing shows underground ducts carrying power cable which has already been installed. M. H. #22 means manhole 22, and M. H. # 23, manhole 23. The de-energized power cable is to be tapped at M. H. #22 and lines run from there overhead to dead end at the rear of building 126. Lines must be run underground from the manhole to the pole, up the pole to the pothead, and from the pothead to the conductors, which are strung on the crossarms. Behind building 126, lines must be run down the pole to a pothead, from the pothead through an underground conduit to a concrete slab, to a pothead, through a disconnect switch, and then over to a transformer bank.

In figure 8–7B, the electrical layout has been added to the plot plan. Notice the references to general notes and the specific notes giving approximate distances and wire sizes, as well as the references to detail drawings. The general notes for this drawing are shown in figure 8–8.

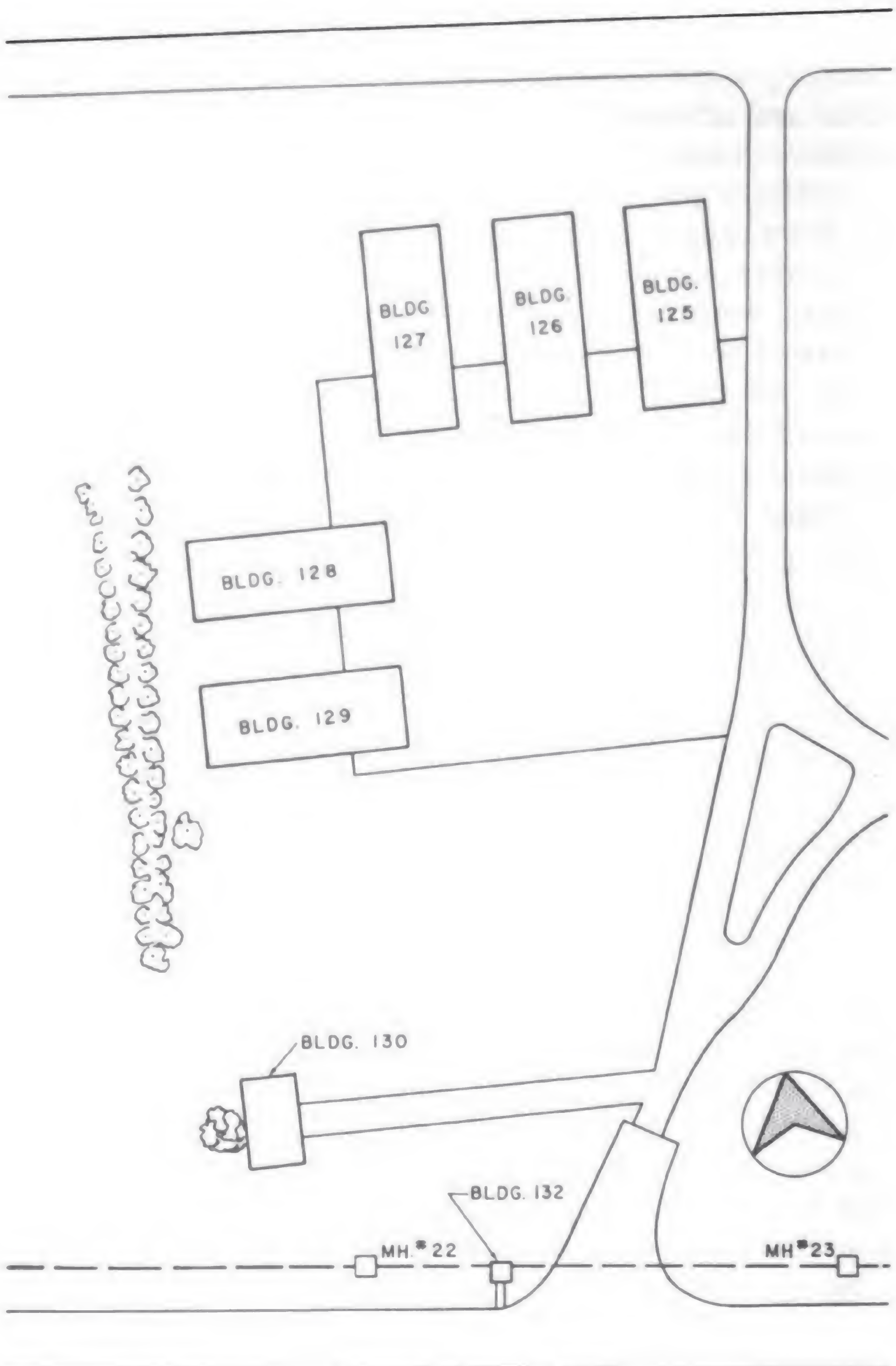


Figure 8–7.—A. Plot plan, showing construction and location of underground cable. B. Plot plan showing lines running to building 126.

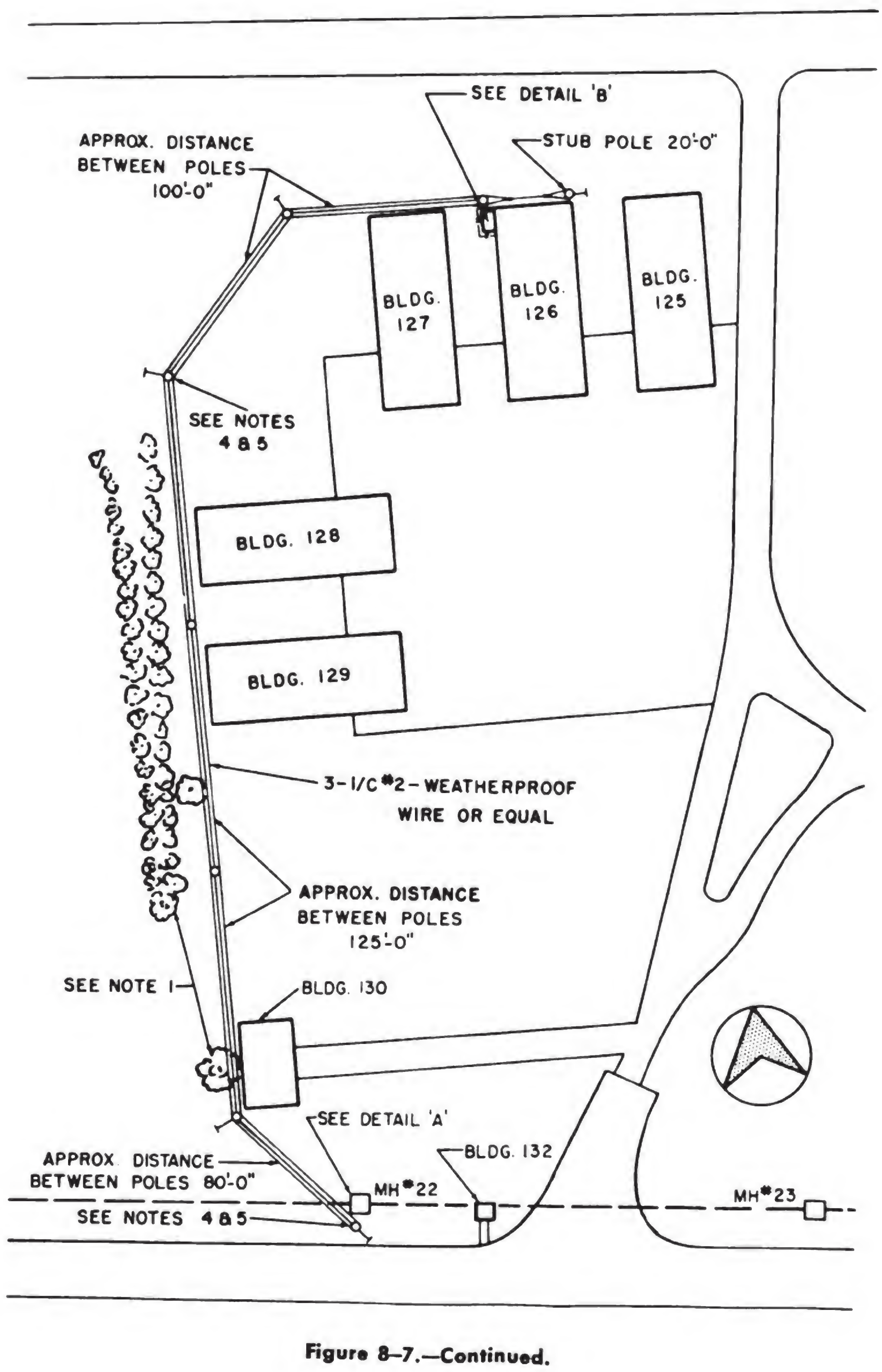


Figure 8–7.—Continued.

Note 1 specifies that the trees are to be trimmed or removed as directed by the construction officer. Note 4 specifies that the crossarms are to be single except at each end of the line and at points where the line changes direction. This note also specifies the type of crossarm to be used and the insulator pin spacing. Note 5 specifies the method of guying the poles and requires that two strain insulators be inserted into each guy line.

GENERAL NOTES -

1 - TREES OBSTRUCTING POLE LINE TO BE TRIMMED OR REMOVED AS DIRECTED BY CONSTRUCTION OFFICER.

2 - PROVIDE LIGHTNING ARRESTERS, AT EACH END OF POLE LINE, ON ALL THREE OVERHEAD WIRES. GROUND LIGHTNING ARRESTERS WITH SUITABLE BARE WIRE CONNECTED TO DRIVEN GROUND ROD.

3 - INSULATORS TO BE PORCELAIN, PIN TYPE, INSULATOR PINS TO BE LOCUST WOOD OR EQUAL.

4 - TERMINAL POLES, AND POLES AT POINT OF CHANGE IN LINE DIRECTION, TO HAVE DOUBLE CROSS-ARMS: ALL OTHER POLES, SINGLE CROSS-ARM. CROSS-ARMS TO BE STANDARD 4 PIN, 5'-7"x 3 1/2"x 4 1/2", PIN SPACING 3'-0" ON CENTERS AND 14 1/2" ON SIDES.

5 - TERMINAL POLES TO HAVE ONE GUY; POLES AT POINT OF CHANGE IN LINE DIRECTION TO BE GUYED ACCORDING TO STANDARD PRACTICE. EACH GUY LINE TO HAVE TWO PORCELAIN STRAIN INSULATORS; THE LOCATION AND SPACING OF STRAIN INSULATORS AND GUY ANCHORS TO BE IN ACCORDANCE WITH STANDARD PRACTICE.

6 - MATERIAL AND WORKMANSHIP SHALL CONFORM TO ALL STANDARD CODES, REGULATIONS AND SPECIFICATIONS LISTED IN BUREAU OF YARDS AND DOCKS SPECIFICATION NO. 9Yf.

Figure 8–8.—General notes.

Figure 8–9 shows the detail *A* indicated on figure 8–7B. Exact dimensions must be given for the location of the pole (centerline of pole 8 feet from centerline of manhole). The conduit from the manhole to the pole is represented by a dotted line, indicating that its run is underground and not visible. Notations on the detail specify the materials and sizes to be used for the various items shown. Section indications on the drawing refer to an elevation showing the pole construction.

This section, or elevation, is shown in figure 8–10. Here the type of pothead to be used and the length and class

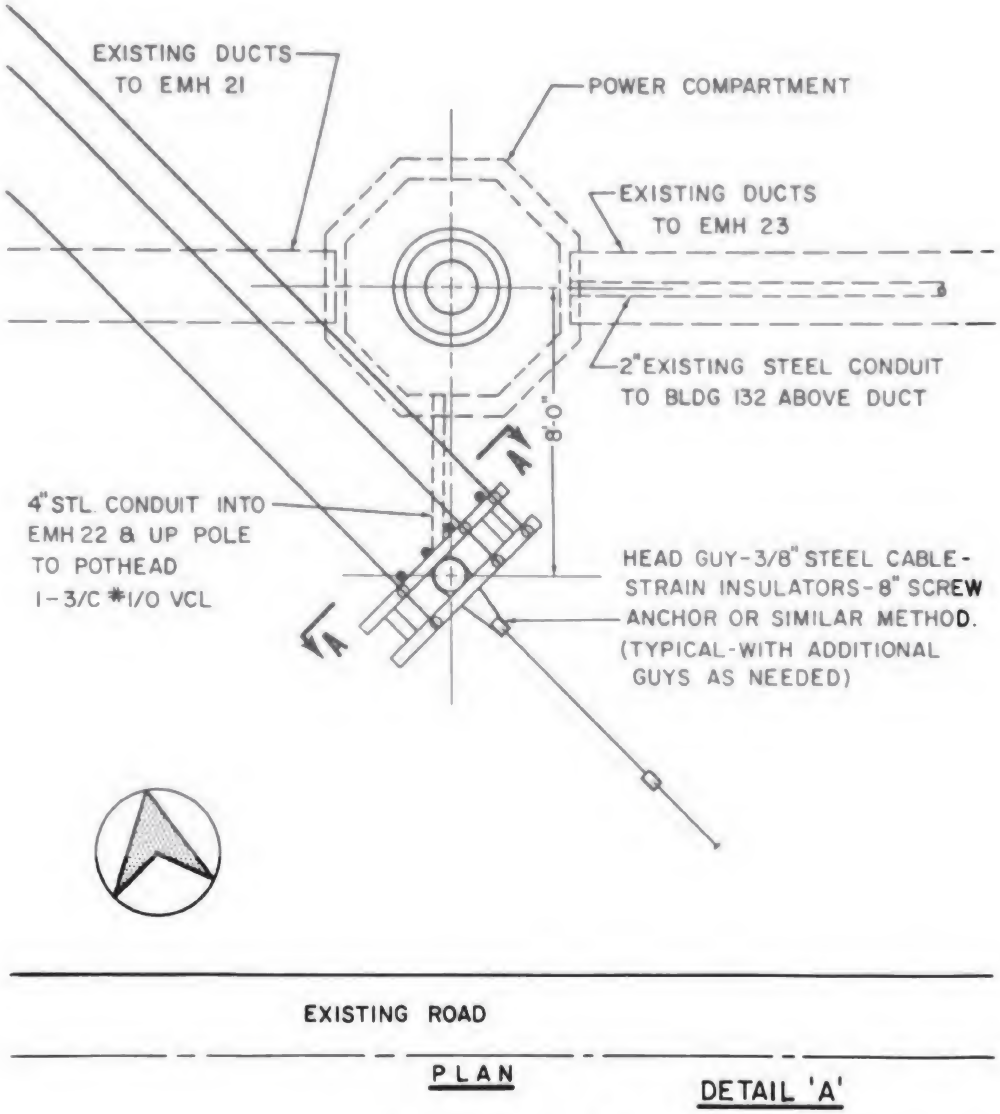


Figure 8–9.—Detail A.

of pole are specified, and further references are made to the notes.

Now, look at figure 8–11. This is a photograph of the actual installation shown on the drawing—the starting point of the overhead power line at manhole 22. Most of the run of the overhead line toward building 126 is also visible.

The detail *B* referred to in figure 8–7B is shown in figure 8–12. This shows the installation behind building 126 where the overhead line terminates. The pole where

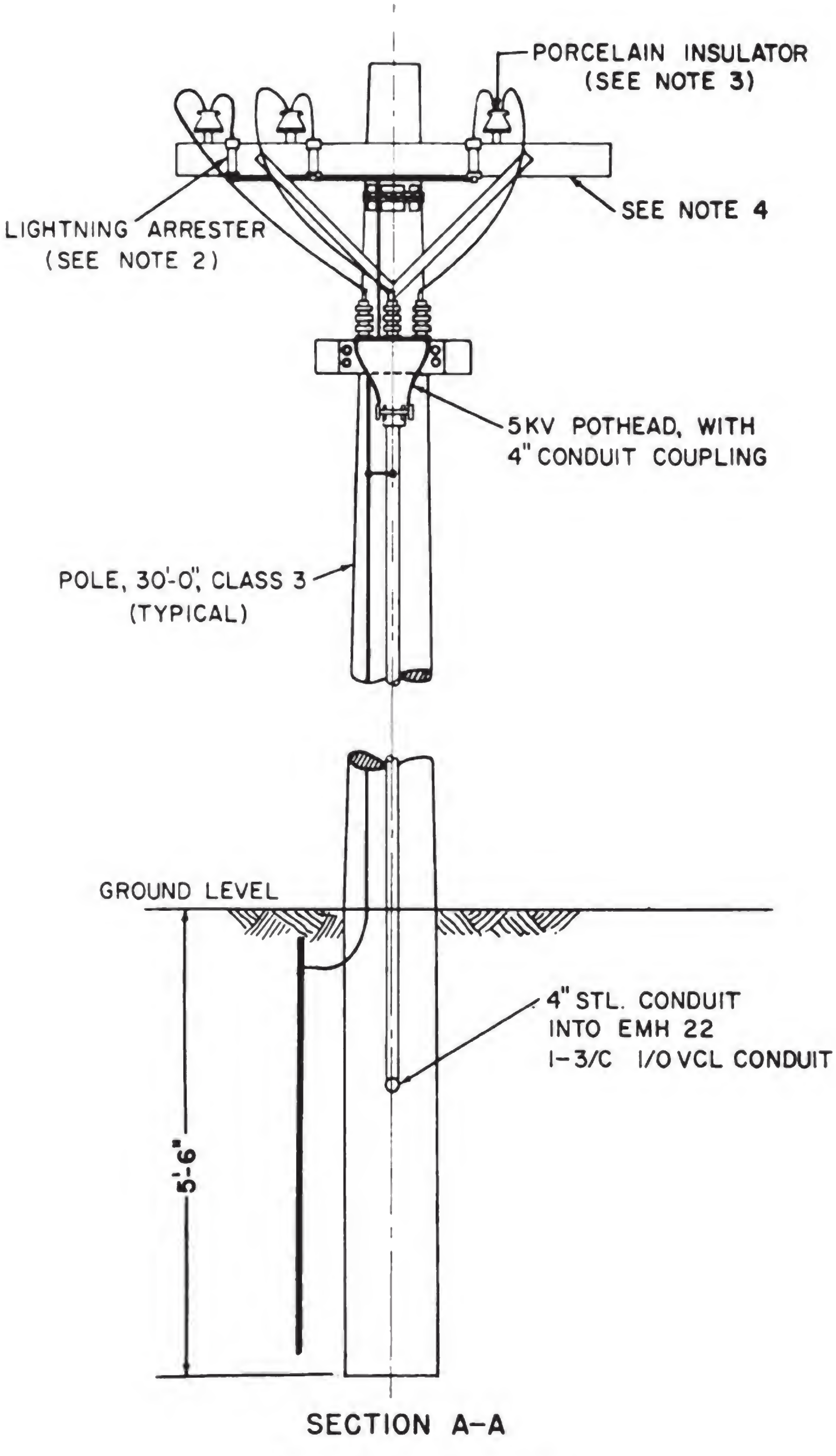


Figure 8-10.—Section A-A.

Figure 8-11.—Starting point of the overhead power line at the manhole.

it dead ends is shown in the lower left corner. Notice the double crossarms, the location of the pothead, and the method of guying the pole. For this pole, a stub guy is specified.

From the pole to the transformer bank, the underground conduit is drawn with dotted lines. The materials and placement of this conduit are given in a note. The conduit runs under the concrete slab on which the transformers are placed. Section *A-A* gives the dimensions of the slab and specifies that wire mesh is to be used for reinforcement and that this mesh is to be embedded in the slab from one end to the other end and from one side to the other.

To support the bus run along the primaries of the transformer, angle iron posts, 3 by 3 inches in size, will be used. These are indicated on the drawing with a leader and a note. Also, either an angle iron or another type of support must be used to support the six cutouts, and the detail shows a wire fence around the concrete slab of the transformer bank.

From the transformer secondaries, underground conduits run to the building. These may be drawn the same

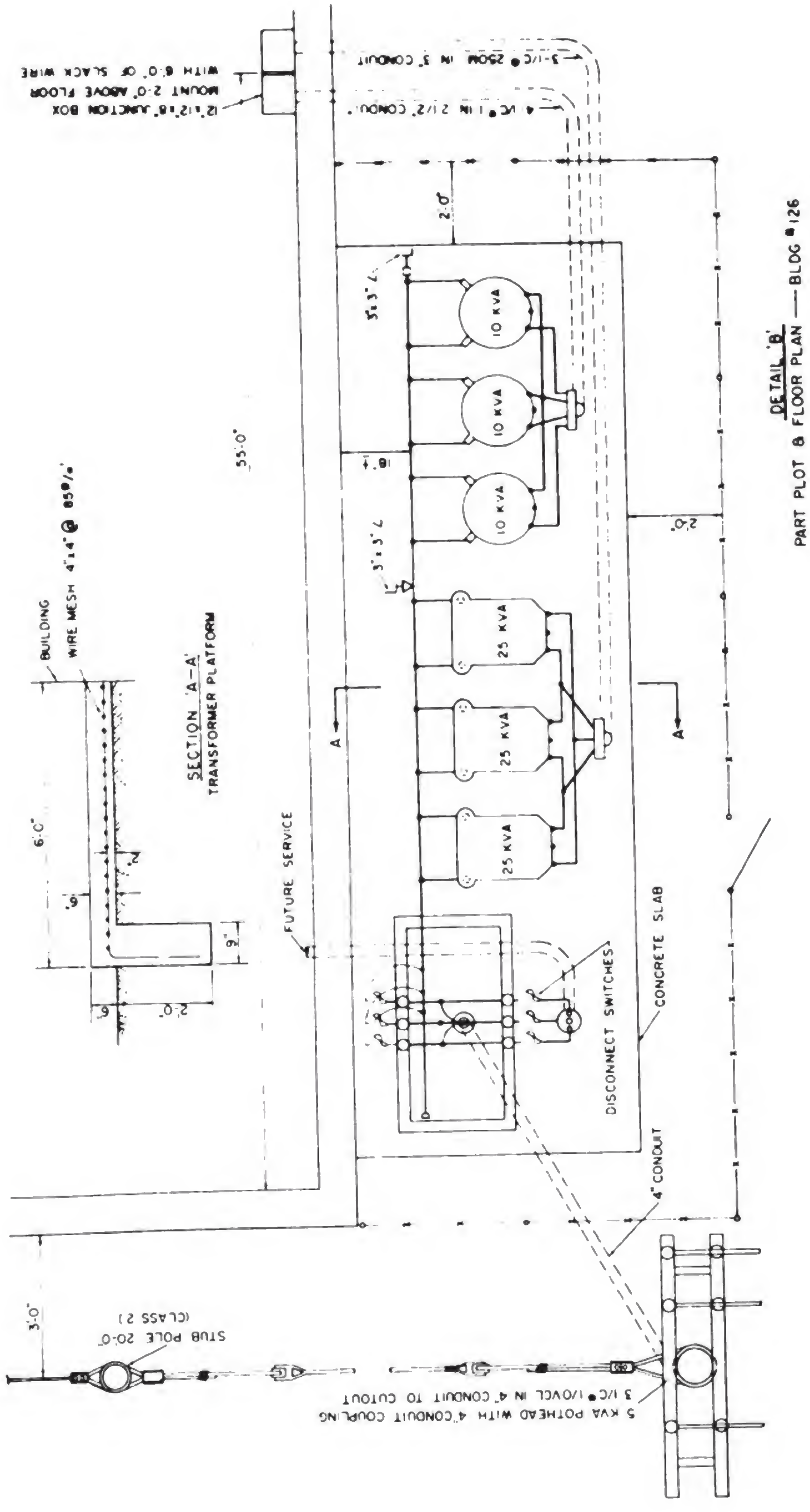


Figure 8-12.—Detail B.

size, although one is 2½ inches in diameter and the other 3 inches. Finally, a note indicates the dimensions relating to the junction box in the building.

The wiring diagram, shown in figure 8–13A, is the single-line type and gives the entire wiring system from the duct and manhole to the point where the wiring is brought up inside of building 126. At this point the interior wiring system begins. The complete wiring diagram is shown in figure 8–13B.

In the wiring diagram, the equipment and its sequence in the circuit, the number and size of the wires, and the transformer connections are all shown at a glance. Notice how the transformer connections are illustrated. The three 25 KVA's are connected delta-delta and the three 10 KVA's are connected delta-Y.

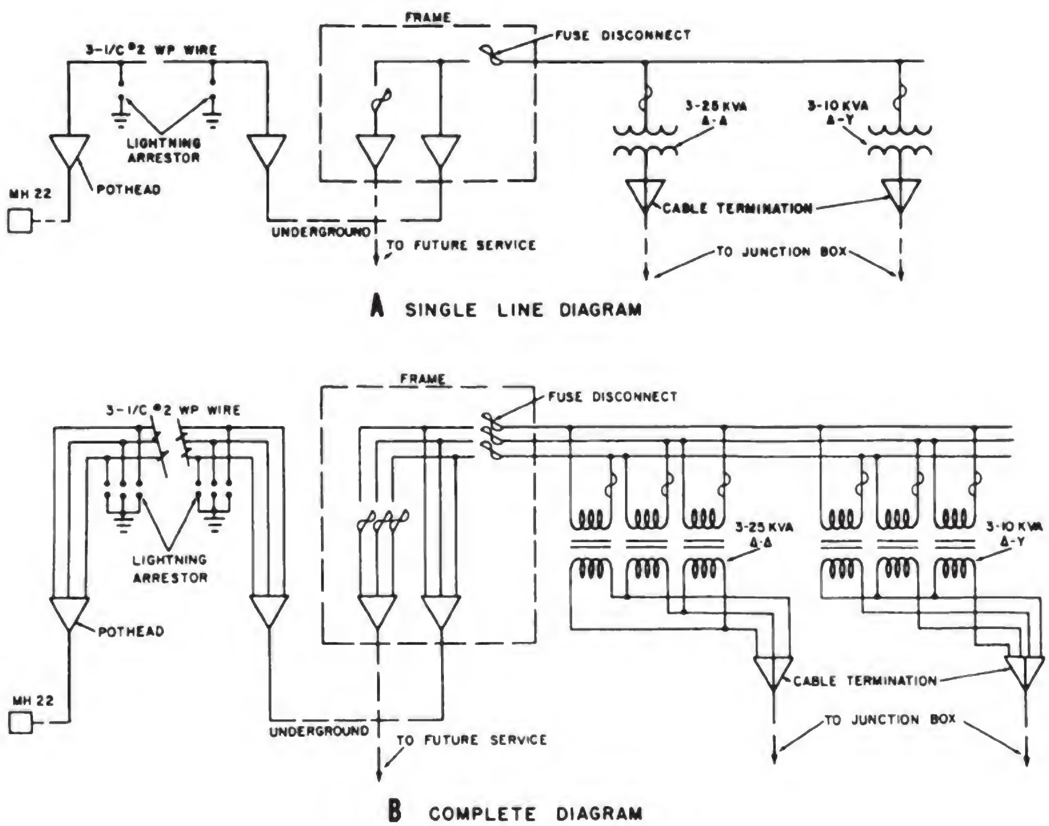


Figure 8–13.—A. Single-line wiring diagram. B. Complete wiring diagram.

Figure 8–14.—Terminating point of the overhead power line behind building 126.

Figure 8–15.—Transformer banks.

Figures 8–14, 8–15, 8–16, and 8–17 show the actual installation at building 126. If you had difficulty visualizing any of the objects shown on the drawing, study these photographs carefully.

Figure 8–16.—Closeup view of disconnect switches and 25 KVA transformers.

Figure 8–17.—Closeup view of bus bar and transformers.

Interior Wiring Layouts

Building 126 and the four other large buildings in the same group are 40- by 100-foot quonset huts. Figure 8–18 shows the interior of such a quonset. Since a quonset is always erected in the same way, it is unnecessary to require a draftsman to redraw the plans every time somebody wants a new quonset. A floor-plan typical of a Standard Bureau of Yards and Docks drawing is shown in figure 8–19.

Occasionally, it is necessary for battalions to make slight revisions or additions to these drawings in order to take care of local conditions. Drawings made showing

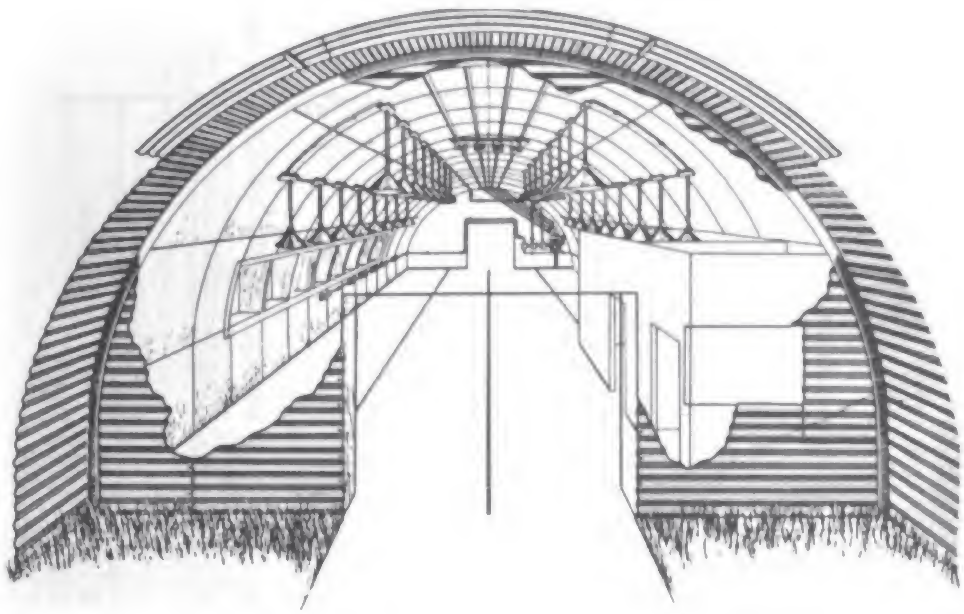


Figure 8–18.—Interior view of a 40- by 100-foot quonset.

the actual as-built conditions when such revisions have been made are called Record Drawings, and you may be called on to make a great number of these.

Besides Record Drawings, you may be required to make the preliminary electrical drawings which, along with structural and architectural drawings, are required to justify a construction project. You may also be required to make the electrical drawings for relatively uncomplicated projects or for temporary structures.

In figure 8–20, a floor plan for a single floor of an office building is shown. This is the type of drawing you may be required to prepare. It shows a service entrance, service switch, and a panelboard from which two branch circuits radiate to provide two convenience outlets and the ceiling outlets in a storeroom and four offices. Such a plan shows where the lights, switches, and other electrical devices are actually placed in a building, but it does not show the proper connections of the interior wiring system.

To show proper connections, an interior wiring dia-

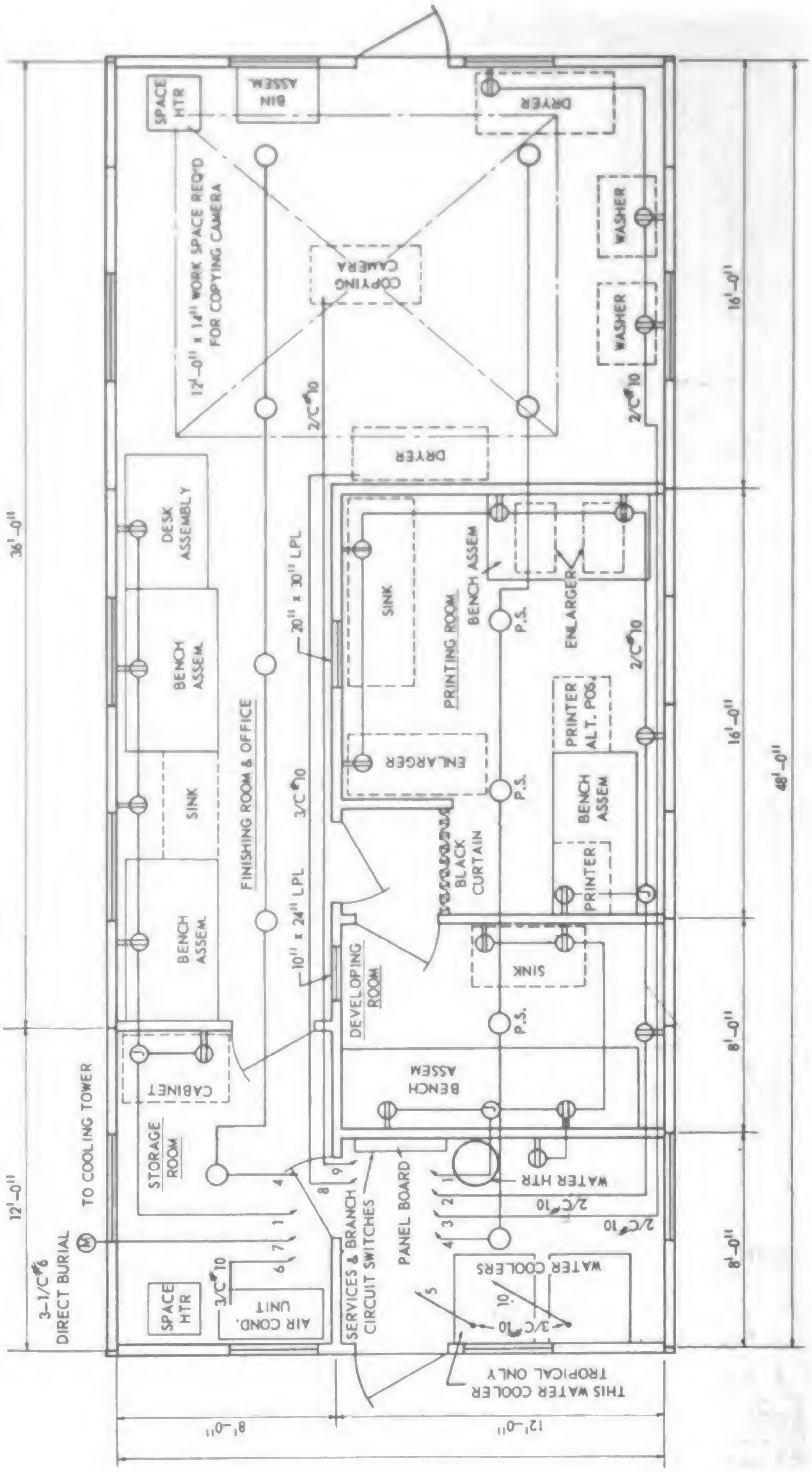
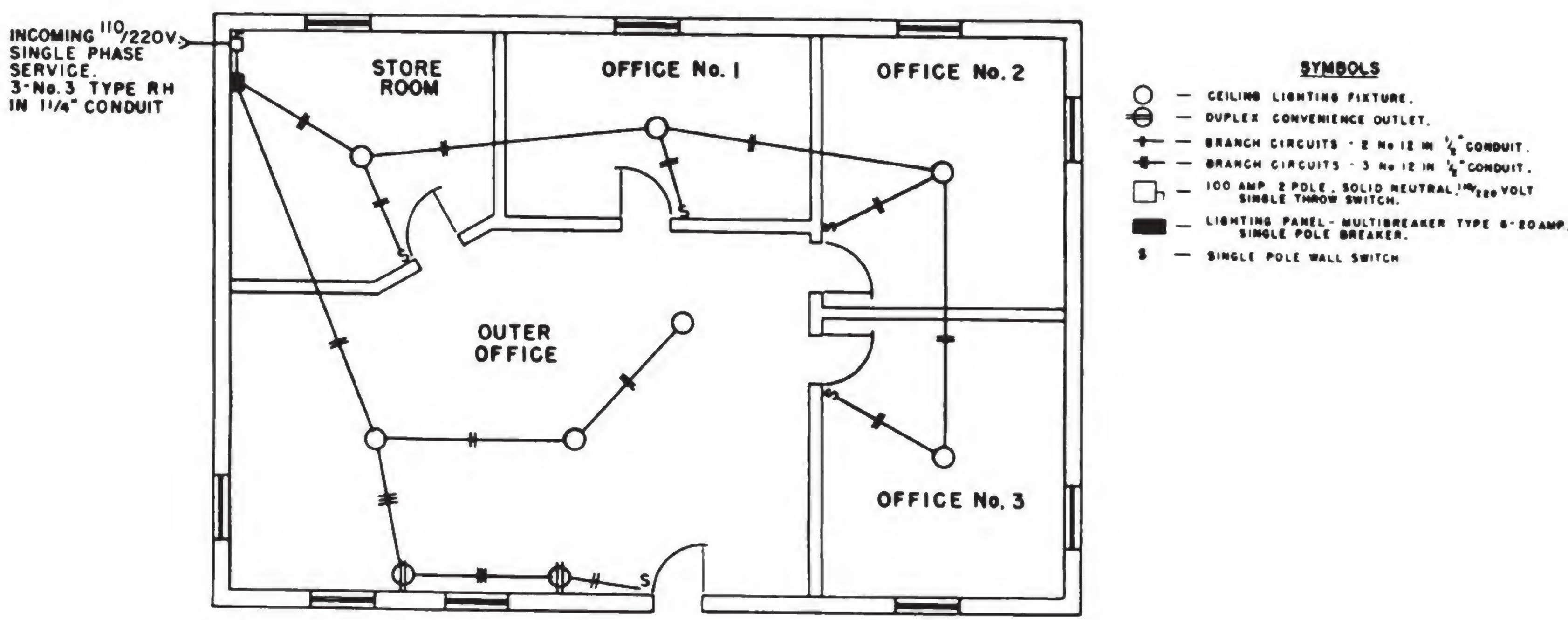


Figure 8–19.—A typical floor plan for a quonset hut.



FLOOR PLAN

SCALE: 1/8" = 1'-0"

Figure 8–20.—Electrical plan.

gram is drawn. The wiring diagram in figure 8–21 shows the connections for the plan in figure 8–20.

The service entrance shown in the diagram is fed with a single-phase three-wire system. The value of the voltage between the two outside wires is 230 volts. The voltage between any one of the outside wires and the middle, or neutral wire, is 115 volts. This setup allows electrical devices rated at either 230 volts or 115 volts to be operated. For example, a 230-volt single-phase motor may be connected between the two outside wires, while a 115-volt light can be tied between the neutral wire and one of the outside wires.

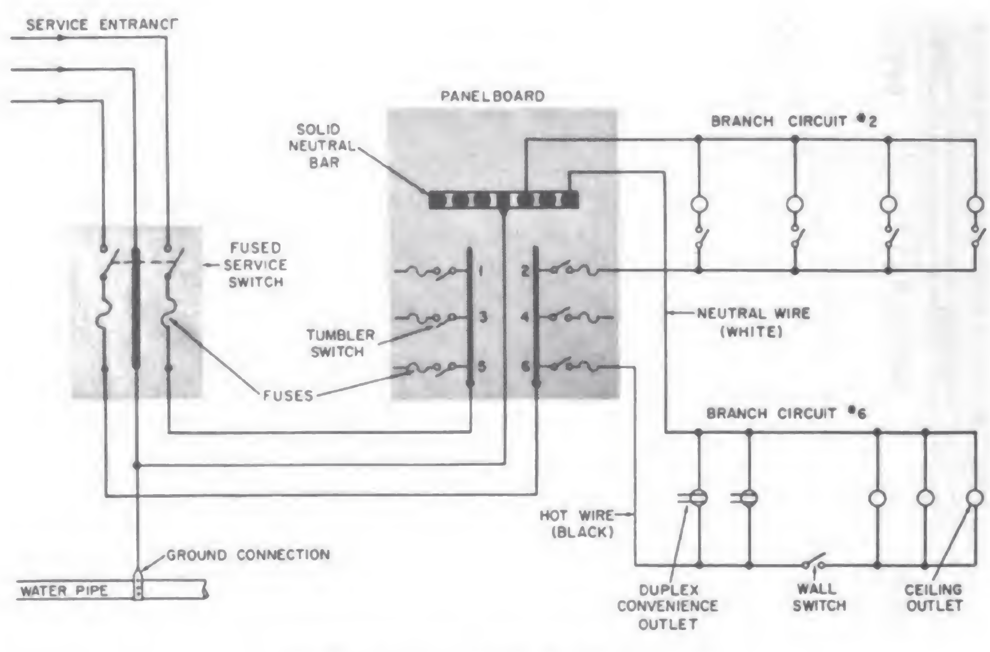


Figure 8–21.—Interior wiring diagram.

The three wires are tapped onto the outside service leads and enter the building through a metal conduit. After entering the building, the wires are trained over and connected into a service switch. The wires running between the switch and the outside of the building are termed the service-entrance conductors.

The service switch consists of two hinged copper blades that work together. In the ON position, the blades are inserted in series with each of the outside wires and form a continuous circuit. In the OFF position, the blades are pulled open and cause a break in the line. Opening the switch cuts off the power from all parts of the interior wiring system. Included in the metal box with the switch is a fuse which automatically opens the circuit when the current goes above its rated values.

Notice that the middle wire is not broken by a switch or fuse but comes straight down and splits with one wire bearing off to the right and the other grounded on a water pipe. This ground to the water pipe keeps the voltage on the wire at zero or ground potential. Since it is not a live wire, there is no need to break its circuit at the service switch.

From the service switch, the wires are run to the panelboard. This is the distribution center. Inside the panelboard, each of the two hot wires connects to a vertical copper strap, and the neutral wire connects to a horizontal copper strap. From these three points, the branch circuits radiate to the lights and motors in the building. Since the current which each branch circuit may carry is limited by the size of wire used, the number of branch circuits depends on the number of lights and motors.

The panelboard in figure 8–21 is set up for six branch circuits, but only two are shown on the drawing. Look at branch circuit No. 6. It consists of two wires, one coming from the neutral bar and the other from the live bar. The live or hot wire is separated by a fuse and switch from the live bar. From the panelboard, the hot wire runs to a pair of duplex convenience outlets to which it is directly connected. The neutral wire is directly connected to the other side of the outlets. Then both the hot wire and the neutral wire continue to three ceiling outlets, but between the convenience outlets and the ceiling outlets, a switch breaks the hot wire. With the switch open, all three ceiling lights will be off at the same time. Branch

circuit No. 2 starts out from the panelboard in the same manner, but each light in the branch has a separate switch.

Shipboard Drawings

Drawings for the complex shipboard systems are prepared by BuShips, and it is unlikely that you will have occasion to do any layouts for shipboard installations. However, you should have some understanding of the ways in which shipboard distribution systems vary from shore based systems. For one thing, shipboard systems are not grounded, for another direct current is used far more often than ashore.

The design of a shipboard power distribution system varies with a vessel's function. AC systems are installed in battleships, carriers, cruisers, destroyers, escort vessels, and numerous auxiliary vessels. DC systems are installed in submarines, small surface vessels, and large auxiliary vessels with considerable deck machinery that requires DC service for its operation.

On major combat ships and some auxiliaries, there are three main parts to the power distribution system:

1. Ship's service distribution system, which includes the main generators, switchboards, distribution panels, and cables furnishing the ship's normal supply of electric power.

2. Emergency distribution system, which includes one or more emergency generators and an emergency distribution system to furnish a limited amount of power for the operation of vital loads when there is a failure of the normal power supply.

3. Casualty power distribution system, which includes a system of portable cables and connection terminals for making temporary electrical connections if the permanently installed ship's service and emergency distribution systems are damaged.

A ship's service AC power system may consist of from two to eight turbine-drive generators that supply three-

wire three-phase 450-volt 60-cycle service to a number of generator and distribution switchboards. To minimize the possibility of damage to more than one switchboard by a single casualty, the switchboards and associated generators are usually located in separate engineering spaces. The lighting system is supplied from the secondaries of several transformer banks. Each of these banks consists of three single-phase transformers connected in delta on both primary and secondary sides. The primaries are connected to a three-phase 450-volt ship's power. The secondaries supply three-wire three-phase 117-volt 60-cycle service for the lighting system.

A typical power distribution system in a destroyer is shown diagrammatically in figure 8–22. The ship's service generator and distribution switchboards are interconnected by bus ties so that any switchboard can be used to supply power from its generator to one or more of the other switchboards. These bus ties also connect two or

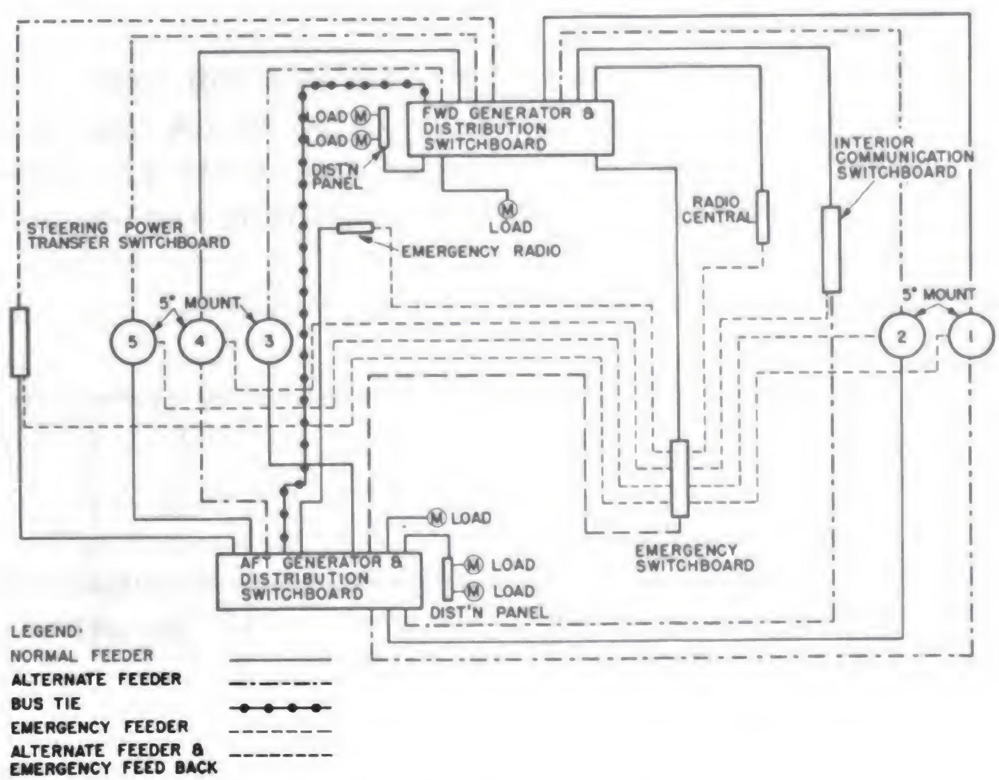


Figure 8–22.—Power distribution system in a destroyer.

more switchboards so that the generating plants can be operated in parallel or the switchboards may be isolated for split-plant operation. Power is supplied directly from the ship's service generator and distribution switchboard to large and important loads, such as the steering gear and gun mounts, and to other loads in the immediate vicinity of the switchboards.

Some ships have three-wire DC generators capable of supplying 240 volts between the two live wires to the power circuits and 120 volts between each live wire and a neutral to the lighting circuits. This arrangement permits power to be transmitted from the source at 240 volts and utilized at the load at 120 volts. The higher transmission voltage reduces the line current and copper losses and thus increases the efficiency of transmission. The decrease in line current and loss becomes appreciable with motors above one or two horsepower. Lighting loads are balanced across the two sides of the three-wire circuit with the neutral wire carrying only the unbalanced current.

The three-wire generator has a balance coil connected across the armature as shown in the schematic diagram of figure 8–23. The coil acts as a transformer and provides a mid-tap for the neutral connection, thus establishing 240 volts between the two outside wires and 120 volts between each outside wire and the neutral.

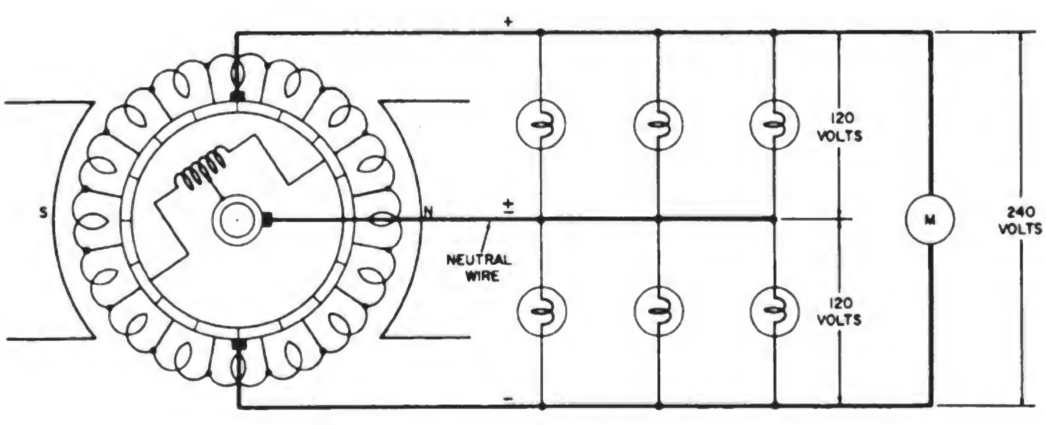


Figure 8–23.—Three-wire DC generator.

ELECTRICAL CABLE

There are many different types of electrical cables installed to suit the varying conditions of heat, cold, dryness, dampness, vibration, flexibility, and shock found on naval vessels or at shore bases.

The types of electric cable used by the Navy for shipboard wiring are identified by a standard system of lettering and numbering which gives a more detailed breakdown than do conventional stock numbers used by supply services. The letters and numbers tell exactly the kind of cable used on the run. The cables themselves bear a metal or fiber tag stamped with the same letters and numbers. The first letters tell how many conductors are in the cable. "S" stands for single conductor, "D" for double conductor, "T" for triple conductor, "F" for four conductors, and "M" for multiple conductors to the cable. A more complete listing of cable designations is given in appendix IV at the back of this book.

The numbers following the letters may indicate one or more of the following:

1. Cross sectional areas of the conductor in thousands of circular mils.
2. Number of conductors.
3. Stranding of conductors.
4. Number of twisted pairs.

If you are uncertain about a type of cable, its letter designation, or its use, you will find considerable information in compact, tabular form in the *Cable Comparison Guide,* NavShips 250–660–23. Descriptions and illustrations of various types of wire can also be found in Navy stock lists.

The Bureau of Ships has adopted the channel method of illustrating cable diagrams. This method eliminates the use of individual lines to represent each cable and instead employs a heavy line to illustrate more than one cable, with the cables fanned out and identified at terminating points. The method reduces drafting time and also the size of drawings.

There are several systems of wiring in use ashore. One of these consists of open knob-and-tube wiring, which is illustrated in figure 8–24. This is used where very low-cost wiring is desired and where appearance is no consideration. Another system consists of concealed knob-and-tube wiring, shown in figure 8–25. This was the earliest system used in residential work. A third system consists of rigid conduit. A type of rigid threaded conduit with fittings is shown in figure 8–26.

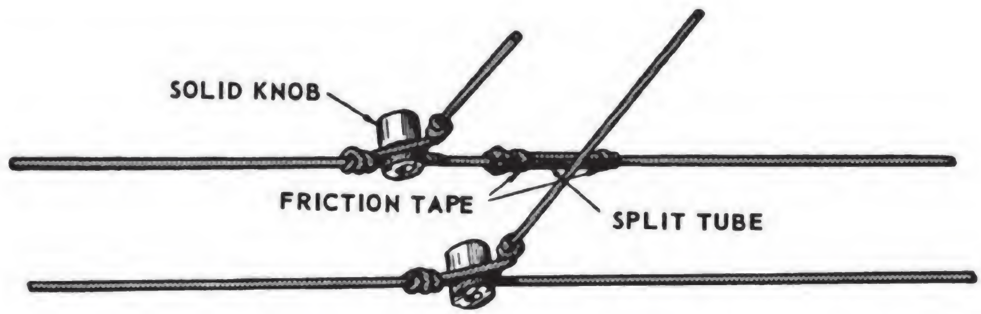


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Figure 8–24.—Open wiring on porcelain knobs, and protection where wires cross.

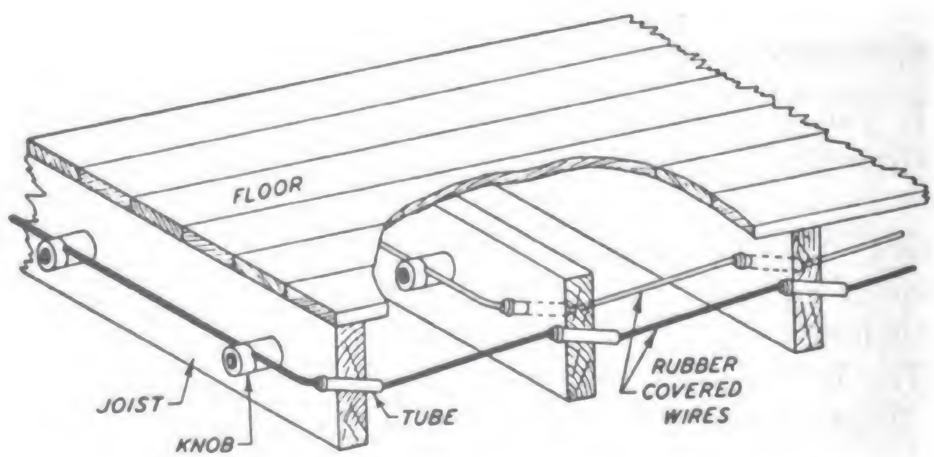

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Figure 8–25.—Concealed knob-and-tube wiring.

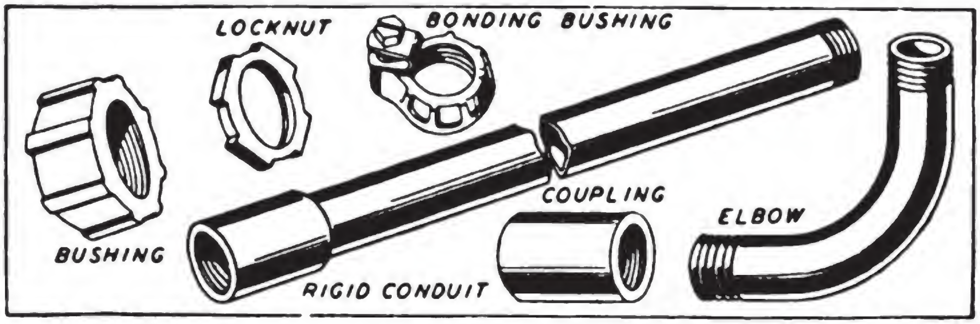

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Figure 8–26.—Rigid conduit and fittings.

In the Navy, two other systems, nonmetallic sheathed cable and armored cable, are the main systems used. Nonmetallic sheathed cable, often called Romex because the first manufacturer to develop it used this as a trade name, is rubber-insulated wire enclosed in a protective braid covering which has a high resistance to moisture, flame, and mechanical injury. A simple quonset-hut lighting installation using Romex is pictured in figure 8–27.

The system shown in figure 8–27 consists of a lighting circuit extending lengthwise at the top of the hut, with a switch at the doorway. An enlarged view of the lampholder circuit shows you how the Romex is installed. The lampholder itself is not fastened to the ceiling. It is supported by the Romex which is secured to the masonite ceiling with cable clamps.

Armored cable, known as BX because that was the trade name of a manufacturer who first developed it, is insulated wire protected by a flexible metal cover. To run armored cable is easy because of its great flexibility, and where rigid conduit must have a coupling at least every 10 feet, armored cable can be run uninterruptedly from outlet box to outlet box. Since the armored cable cannot be threaded, special types of clamp connectors must be used for fastening cable to outlet boxes.

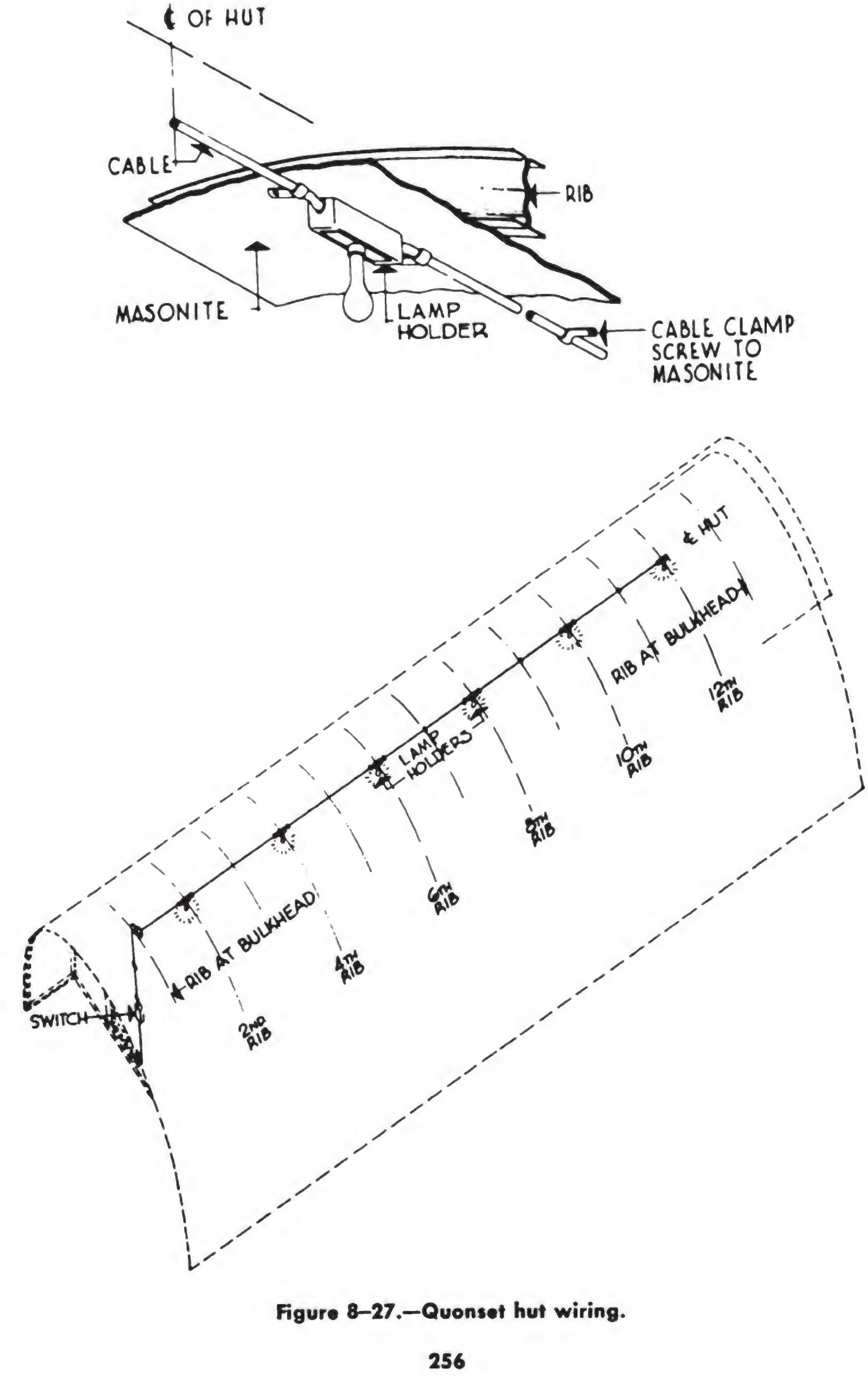


Figure 8–27.—Quonset hut wiring.

TELEPHONE CIRCUITS

Some of the first instruments to successfully carry a human voice by electrical means had no batteries or other sources of power supply. One piece of apparatus served as both mouthpiece and receiver. When someone spoke into it, the vibration of a diaphragm produced an alternating current of sufficient strength to cause the diaphragm of the instrument at the other end of the line to make similar vibrations and to produce sounds like those of the speaking voice.

At its best, this type of sound-powered telephone was good only for communication over very short distances. For greater range, a system similar to that shown in figure 8–28 has proved more satisfactory. In this system, the power was supplied by a battery. The function of the transmitter in this case is to control the current sent over the wires rather than to produce the current.

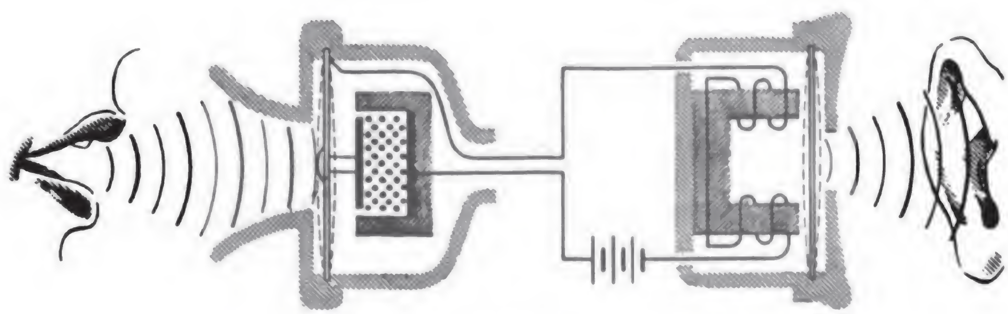


Figure 8–28.—How the telephone works.

The transmitter has a flexible diaphragm attached to a carbon button. The button presses against a mass of carbon granules enclosed in a current-conducting container. When sound waves strike the diaphragm, it vibrates at the same frequency as the sound. Vibration of the diaphragm alternately compresses and loosens the carbon grains. Compression of the carbon decreases the resistance of the microphone. Lessening the pressure on the carbon increases the resistance of the microphone.

Thus the resistance of the microphone varies according to the rate of vibration of the diaphragm, and as a result the current through the circuit also varies.

The receiver has a U-shaped permanent electromagnet with an iron diaphragm held just out of contact with the pole pieces. The position of the diaphragm is determined by the electromagnet whose magnetic strength varies with the strength of the current. Thus changes in current that are caused by vibration of the transmitter diaphragm will make the receiver diaphragm vibrate with the same frequency. When it vibrates, the receiver diaphragm sets up sound waves that are replicas of those striking the transmitter.

You can increase the distance range of a simple telephone circuit by the use of a transformer, or induction coil, as shown in figure 8–29. The step-up ratio in the coil provides a voltage sufficient to overcome the resistance in a line several miles long. However, long distance telephony requires audio frequency amplifiers, which are also known as repeaters.

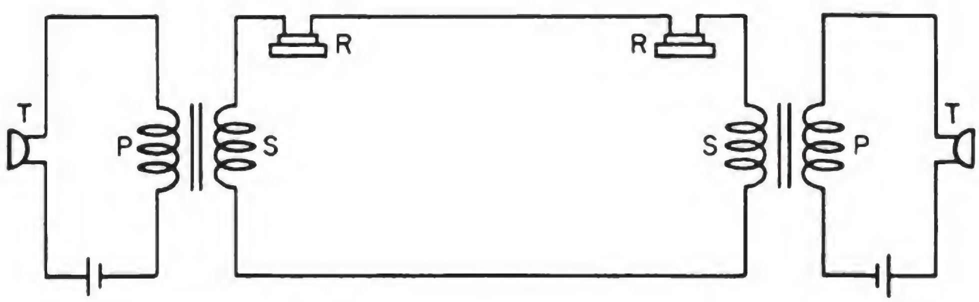


Figure 8–29.—Telephone system with induction coil.

Many of the telephone systems used in the Navy are similar in principle to some early types which have been largely superseded in commercial use. On many advanced bases, you find a battery-operated system that must be rung by hand and which is similar to those formerly used very widely in rural communities. There were some bitter

experiences in the early part of World War II when communication aboard ships was disrupted because the batteries or other power sources were destroyed during battle. Today, practically all ships are equipped with sound-powered telephones for battle stations, although power-operated telephones and other apparatus may be used for normal communication. Large ships have many sound-powered circuits, each designed for a definite purpose. Most of the important circuits have auxiliary circuits which can be used in case of failure of the primary circuit.

The most complicated diagram of a telephone circuit is usually composed of a group of elementary circuits. In order to draw such diagrams, you should know the conventional symbols for the commonly used units of telephone apparatus, and you should understand the functions of the elementary apparatus, such as the transmitter, receiver, induction coil, capacitor, ringer, jack, key, and relay.

Five pieces of telephone equipment—cords, plugs, jacks, signals, and keys—are found in practically every telephone switchboard. A cross section of a local-battery switchboard plug is shown in figure 8–30. The names—tip and sleeve—come from the position and appearance of the contact surfaces on the plug. The springs of the jack with which these surfaces make contact are called by corresponding names. The jack is the device upon which a telephone line is terminated at the switchboard. A view of a switchboard plug inserted in a jack is shown

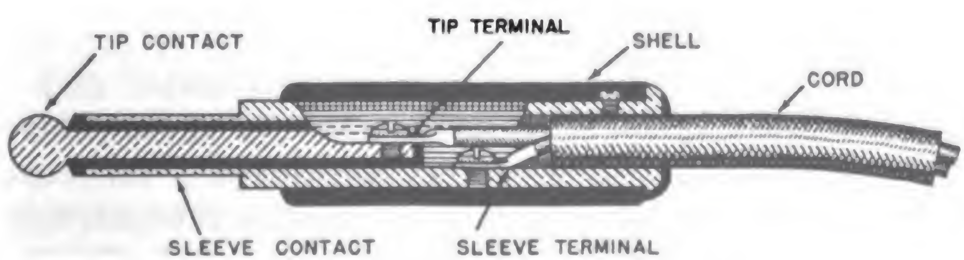


Figure 8–30.—Local-battery switchboard plug.

in figure 8–31. The symbols for each, as they would appear on a circuit diagram, are drawn above. Many different types of jacks and a number of spring arrangements are employed when special operating features are desired.

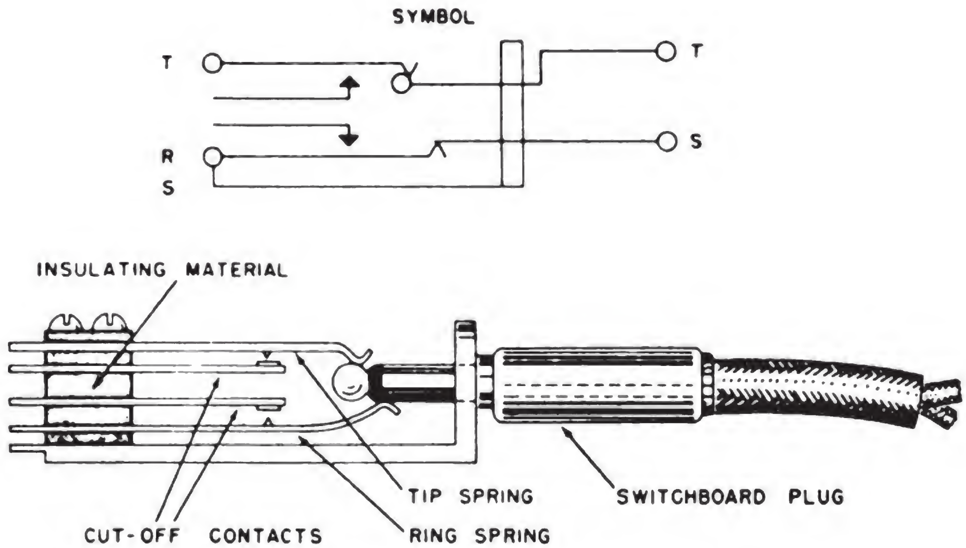


Figure 8–31.—Local-battery switchboard jack with plug inserted.

For local-battery lines, a line drop, which is usually a small shutter, is mounted directly above each jack. To signal the operator, it is necessary to turn the crank of the hand generator mounted in the telephone set before removing the receiver from the hookswitch. This sends 20-cycle ringing current out on the line to operate an electromagnet located behind the panel of the switchboard. The ringing current passes through the winding of the electromagnet, causing the armature to be attracted to the core of the winding. This causes the shutter rod to raise, releasing the shutter or drop. When the shutter falls, it gives the operator visual notice that a person desires to make a call. Since the shutters are placed directly above the jacks with which they are associated, the shutter also tells the operator which telephone is calling. The electromagnet is called the line relay. A diagram of this relay is shown in figure 8–32.

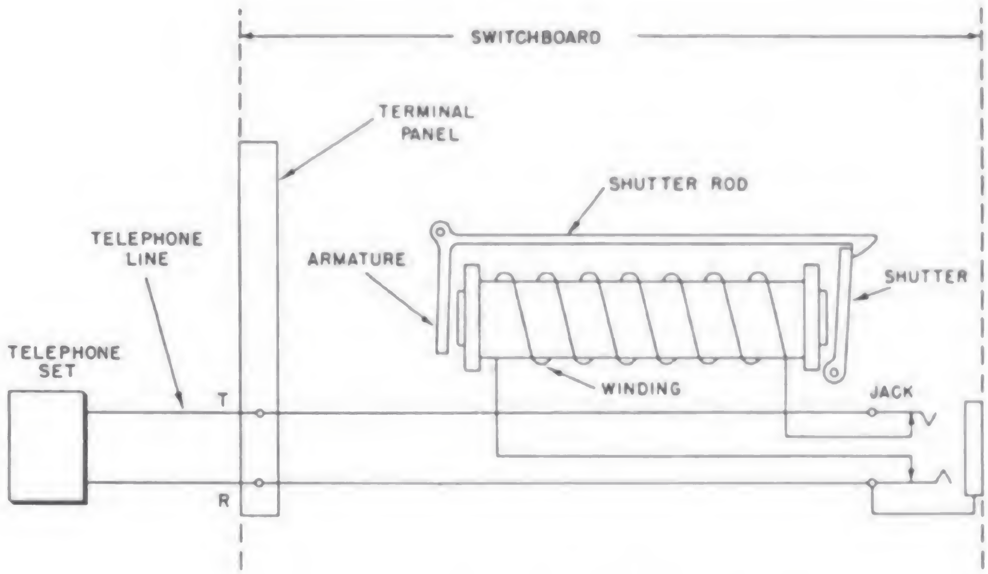


Figure 8–32.—Local-battery line circuit with line drop.

There is one line relay, one drop or shutter, and one jack for each local-battery line connected to a switchboard. The meaning of the word DROP is often enlarged to include the complete unit consisting of the electromagnet and its armature, as well as the shutter.

A key, in a telephone circuit, is a device for opening or closing a circuit. It is a special kind of switch adapted to telephone circuits. Two types of telephone keys are used, the lever type and the push-button type.

The size and permanence of an activity determine the type of switchboard used. Large bases that are to be used for long periods of time naturally use larger sized boards. The lines on a switchboard range from as few as six to as many as several hundred. The construction battalions normally use boards of 12-, 40-, or 57-line capacity.

The function of a switchboard is to act as a central switching point for a large number of phones. Many incoming lines enter the switchboard office, but these lines do not go directly to the switchboard jacks. Instead, they are sent over and permanently terminated on distributing frames. Lines from the switchboard jacks are also brought

over to the distributing frame. Jumper wires interconnect the outside wires to the proper inside wires. One distributing frame in a switchboard office is called an MDF or main distributing frame. An additional frame is termed an IDF or intermediate distributing frame.

Although telephone lines outside of a plant do not normally carry high voltages or high current, protective devices are necessary to safeguard both personnel and telephone equipment. Three types of protective devices placed in lines are heat coils, fuses, and lightning arresters.

Heat coils are used as protection against "sneak" currents. These currents are not great enough to blow a fuse and yet they can damage equipment. The heat coil is so designed that prolonged passage of the sneak current causes contact to be made with a ground wire. Thus the sneak currents are routed to ground before they have a chance to damage the telephone equipment.

The heat coil doesn't open the circuit, but merely bypasses excessive current to ground. If that current becomes too large, it will damage the wires of the outside plant. Thus, it will be necessary to insert fuses in series with the incoming wires.

When lightning strikes exposed telephone wires it produces an excessive surge of voltage. Unless this energy is quickly drained away to ground, it might cause damage to personnel and equipment. Lightning arresters are the "valves" which do the job. They consist essentially of two carbon blocks separated by an air gap. One block is connected to the line wire, and the other is tied to ground. When the high lightning voltage appears on the line, it will break down the air gap between the carbon blocks. Excessive energy can then follow an easy path to ground. When the high voltage disappears, the arc is snuffed out and the line returns to normal.

QUIZ

1. Why is alternating current better than direct current for use where power is to be transferred over long distances?
2. Name two types of advanced base AC distribution systems.
3. What type of distribution system would you find with a Y-connected alternator?
4. What are drawings called which show actual as-built conditions when slight revisions or additions have been made to meet local conditions?
5. What is the place where the wires of an electrical circuit enter a building called?
6. When two of the wires in an interior wiring circuit carry 230 volts and a third wire is neutral, what advantage is gained in terms of operating electrical devices?
7. Why is the neutral wire not broken by a switch or fuse at the service switch?
8. In what types of ships are DC distribution systems installed?
9. What does the first letter on the tag on a cable for shipboard wiring tell about the cable?
10. What is the channel method of illustrating cable diagrams?
11. What two types of cable are mainly used in the Navy for interior wiring of buildings, and what trade names are they called by?
12. What device is used to increase the distance range of a simple telephone circuit?
13. What type of telephone, largely superseded in commercial use, are you likely to find on many advanced bases?
14. What are five pieces of telephone equipment found in practically every telephone switchboard?
15. What is one distributing frame in a switchboard office called and what is an additional frame called?
16. Name three types of protective devices placed in lines, both at the substation and the switchboard office.

CHAPTER 9

TOPOGRAPHIC DRAFTING

INTRODUCTION

Maps, whatever their purpose, must be constructed from facts about an area which are gathered in the field and brought back to the drafting room. The value of the drawings which are produced from these facts depends in large part upon the knowledge and skill of the draftsman interpreting them. As a DMT 1 or C, you should be able to read field notes of surveys and make certain computations connected with them. You should also be able to make overlays from aerial photographs, although the art of interpreting these photographs is a highly skilled one and you can only be expected to have a generalized knowledge of it.

AIRFIELD AND ADVANCED BASE LAYOUTS

The principles used in drafting topographic layouts are very similar to those used in making mechanical layouts. You may work from field notes or from existing drawings. You may be required to make preliminary drawings for use in planning a project or record drawings showing the finished work. In any case, you must be able to follow an engineer's directions accurately, read field notes, make any necessary computations, and have a thorough grasp of the conventions and symbols involved

in topographic drafting. For a description of the methods used in making quantity estimates and bills of materials, read chapter 7, *Structural Drafting*. For a detailed discussion of the measurements and planning involved in airfield construction, read chapter 5, *Surveyor 1 & C*, NavPers 10633–A.

The Bureau of Yards and Docks has prepared various publications which will be of value to you in making advanced base and airfield layouts. You will not be expected to memorize the facts in these publications, but you should have them available for ready reference. Among the most pertinent of these publications are:

- NavDocks P–140, *Advanced Base Drawings*.
- TP–PL–5, *Engineers' Handbook for Planning Navy Advanced Bases*.
- TP–PL–14, *Planning Naval Shore Activities*.
- TP–Te–1, *Surveys, Drawings, and Specifications*.
- TP–Pw–4, *Airfield Pavement*.

SURVEYING COMPUTATIONS

Before leaving the field, the surveyor usually makes a check on his work to determine whether it is accurate enough to bring into the office or whether certain angles and distances should be remeasured. In any survey, a certain standard must be maintained, depending on how great an accuracy is required for that particular work. This precision of measurement standard is usually expressed in terms of 1 divided by a number. For example, $\frac{1}{5000}$ means that the permissible error is 1 foot in 5,000 feet. A surveyor, therefore, may bring notes into the office which contain an error within a specified amount.

Traverses

A traverse is closed if it begins and ends at the same point. In other words, a closed traverse is a closed polygon. The lengths of the courses of a traverse are usually stated in feet and decimal parts of a foot. The direction

of a course of a traverse is given by stating the angle between the course and some known line.

If the angle between a course and a meridian is given, it is either an azimuth or a bearing. An azimuth is the angle measured clockwise between north and the direction of the course. A bearing is given according to the quadrant of the compass, N, E, S, or W, in which the angle falls. The letters preceding and following a bearing define the quadrant of the compass in which the angle falls. For example, the bearing N 65° E is the azimuth angle 065°, and the bearing S 15° W is the azimuth angle 195°. Both azimuths and bearings may be measured either from the true meridian or the magnetic meridian.

If azimuths have been measured to establish the traverse, then when the azimuths are carried around the traverse and back to the first course, the two azimuths measured for the first course should have the same value. The same thing is true for bearings.

Often the direction of each course of a traverse, after the first course, is established by the angle it makes with the preceding course or the prolongation of the preceding course. If the angle is measured from the preceding course, it is an INTERIOR ANGLE. However, it is more common to measure the angle between a course and the prolongation of the preceding course. This may be either an interior or an exterior angle, and it is called a DEFLECTION ANGLE.

The formula for the sum of the degrees of the interior angles in a polygon is $180° (n - 2)$ where n is the number of sides. For example, for a perfect 6-sided polygon, the sum of the angles should be $180° (6 - 2) = 180° (4) = 720°$.

A deflection angle may be either to the right or to the left. If the angle is turned clockwise from the prolongation of the preceding course, it is a RIGHT DEFLECTION ANGLE (R). If it is turned counterclockwise, it is a LEFT DEFLECTION ANGLE (L). Right deflection angles are given a plus

(+) sign, and left deflection angles, a minus (—) sign.

If deflection angles have been measured for a traverse, the algebraic sum of all the deflection angles should equal 360°. Figure 9–1 shows the sketch of a traverse for which deflection angles were measured. Adding the right, or plus, deflection angles, as measured, and subtracting the

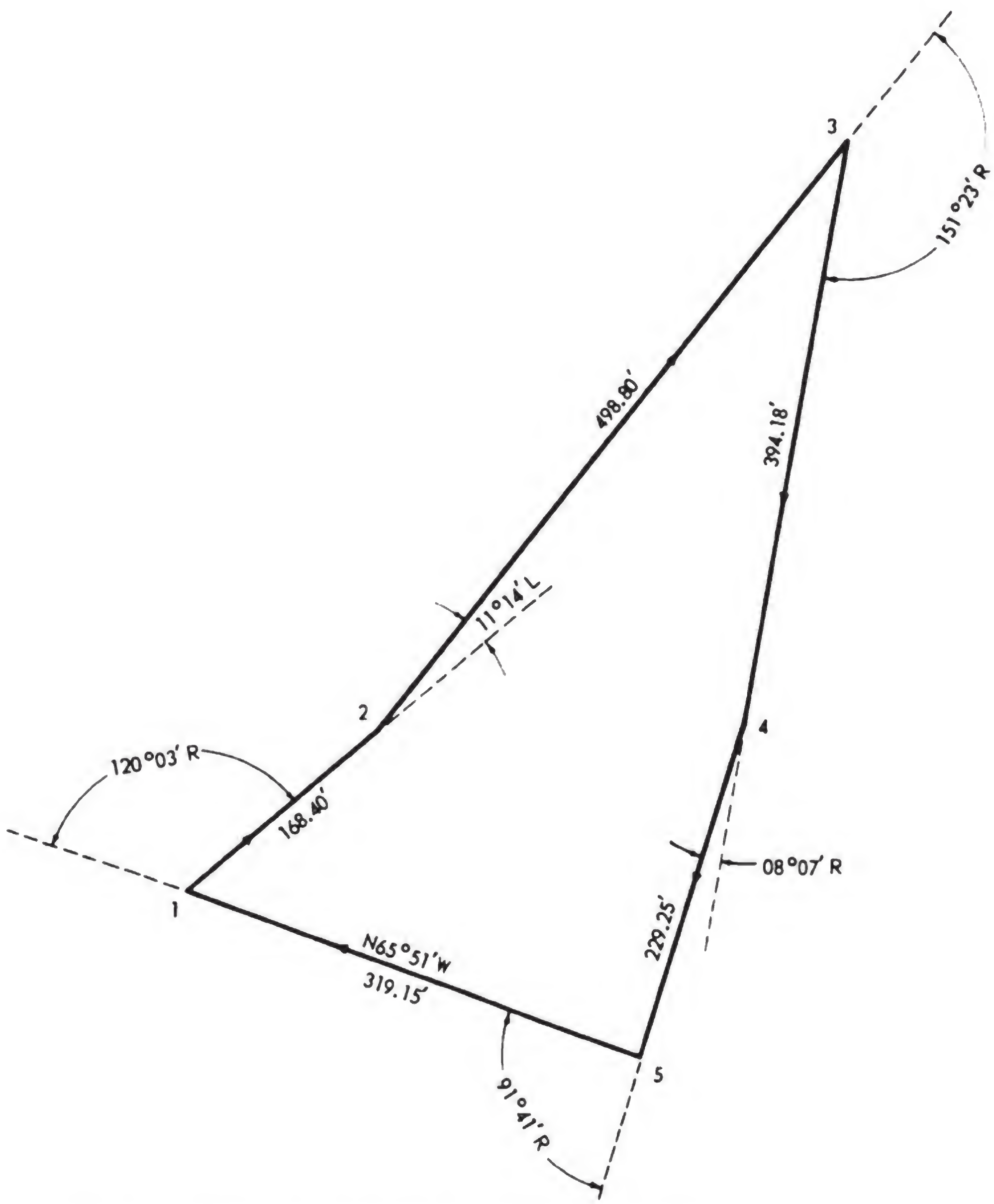


Figure 9–1.—Sketch of a traverse for which deflection angles were measured.

single left, or minus, deflection angle from this sum, you should get

R	91° 41′ 30″		
R	120° 03′ 30″		
R	151° 23′ 00″		
R	08° 07′ 00″		
	370° 75′ 00″		sum of right deflection angles.
minus L	11° 14′ 00″		sum of left deflection angles.
	359° 61′ 00″		or 360° 01′ 00″.

Notice there is an error of 01′. Usually the error is distributed to all angles, but in this case, you may subtract 30″ from the first and second angles so that these angles read 91° 41′ and 120° 03′. Actually, it is not convenience alone that dictates this choice, but the additional fact that the length of the courses between these angles are the shortest and therefore these angles are most likely to have been in error.

It is often necessary in making computations to convert interior angles or deflection angles to bearings. Remember that bearings are measured from the south for the two south quadrants of the compass and from the north for the two north quadrants. (See fig. 9–2A.) For example, in figure 9–2B, the observed bearing of *OA* is N 54° E and angle *AOB* is 112°, angle *BOC* is 36°, and angle *COD* is 93°. Then to calculate the bearing of *OB*, subtract 54° and 112° from 180° to get S 14° E. To calculate the bearing of *OC* subtract 14° from 36° to get S 22° W. To calculate the bearing of *OD* subtract 22° and 93° from 180° to get N 65° W.

Suppose that the deflection angles for the traverse shown in figure 9–1 are to be converted to bearings. The bearing of the first of these angles is given. Set up a worksheet with the stations, adjusted angles, the given bearing, and the length of the courses, as follows:

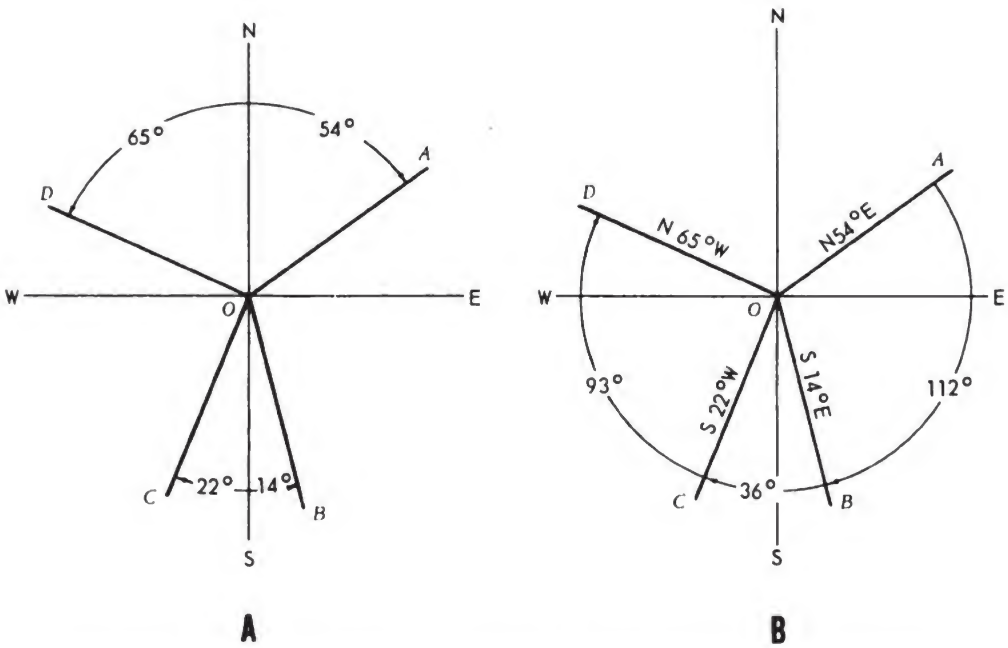


Figure 9–2.—A. Directions from meridian in which bearings are measured. B. Angles to be converted to bearings.

Station	Deflection Angle	Bearing	Length of Course
5–1	91° 41′ 00″ F	N 65° 51′ W	319.15 ft.
1–2	120° 03′ 00″ R		168.40 ft.
2–3	11° 14′ 00″ L		498.80 ft.
3–4	151° 23′ 00″ R		394.18 ft.
4–5	08° 07′ 00″ R		229.25 ft.

The course at station 1–2 has a right deflection angle of 120° 03′, while the preceding course at station 5–1 has a bearing of N 65° 51′ W. Notice that the angle is larger than the bearing. Since it is a right deflection angle, measured clockwise from the bearing, it will fall in the NE quadrant, rather than the NW. Therefore, subtract N 65° 51′ W from the angle 120° 03′ 00″ and the remainder will be the bearing in the NE quadrant. Thus, 120° 03′ R or 119° 63′ − 65° 51′ = N 54° 12′ E, the bearing of the

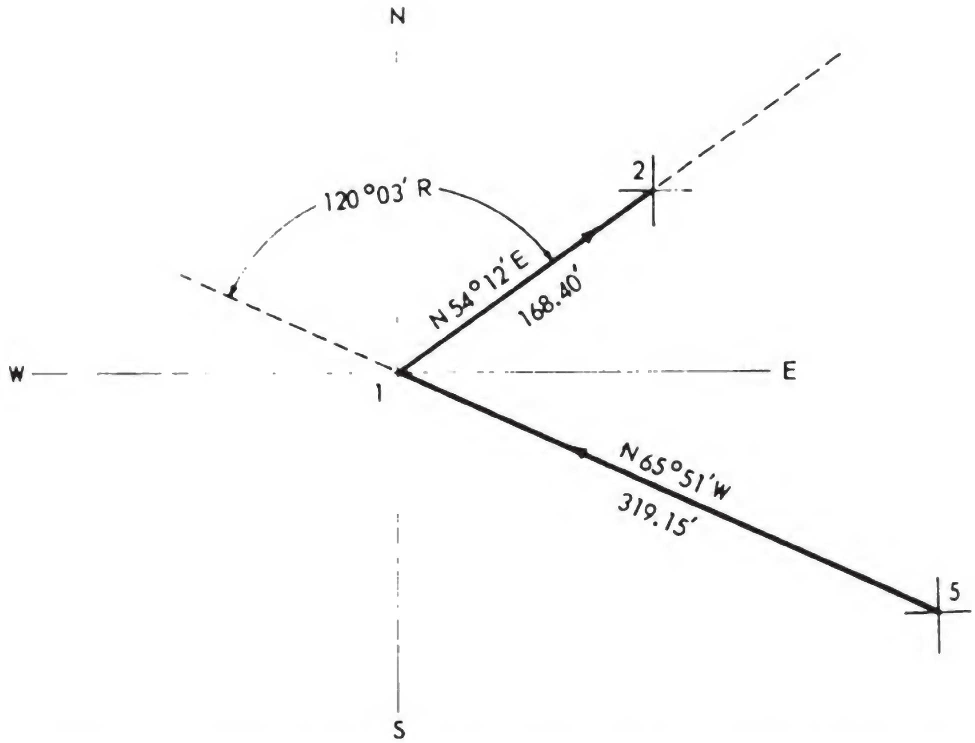


Figure 9–3.—Finding the bearing for a course when an observed angle from a known bearing is given.

course at station 1–2. This is shown in the sketch in figure 9–3.

The other bearings are found in the same manner. Station 2–3 has a left deflection angle of 11° 14′. Since it is a small angle which will fall to the left, that is, toward the meridian, from the bearing for the course at station 1–2, it is subtracted from that bearing. Thus, 54° 12′ or 53° 72′ − 11° 14′ = N 42° 58′ E, as shown in figure 9–4A.

Station 3–4 has a right deflection angle of 151° 23′. This angle will fall to the right of bearing N 42° 58′ E. Obviously it will not fall in the same quadrant and, therefore, since it must be measured from the south meridian rather than the north meridian, subtract the bearing N 42° 58′ E from 180° to get 137° 02′. Then, since this figure is smaller than the deflection angle, subtract it

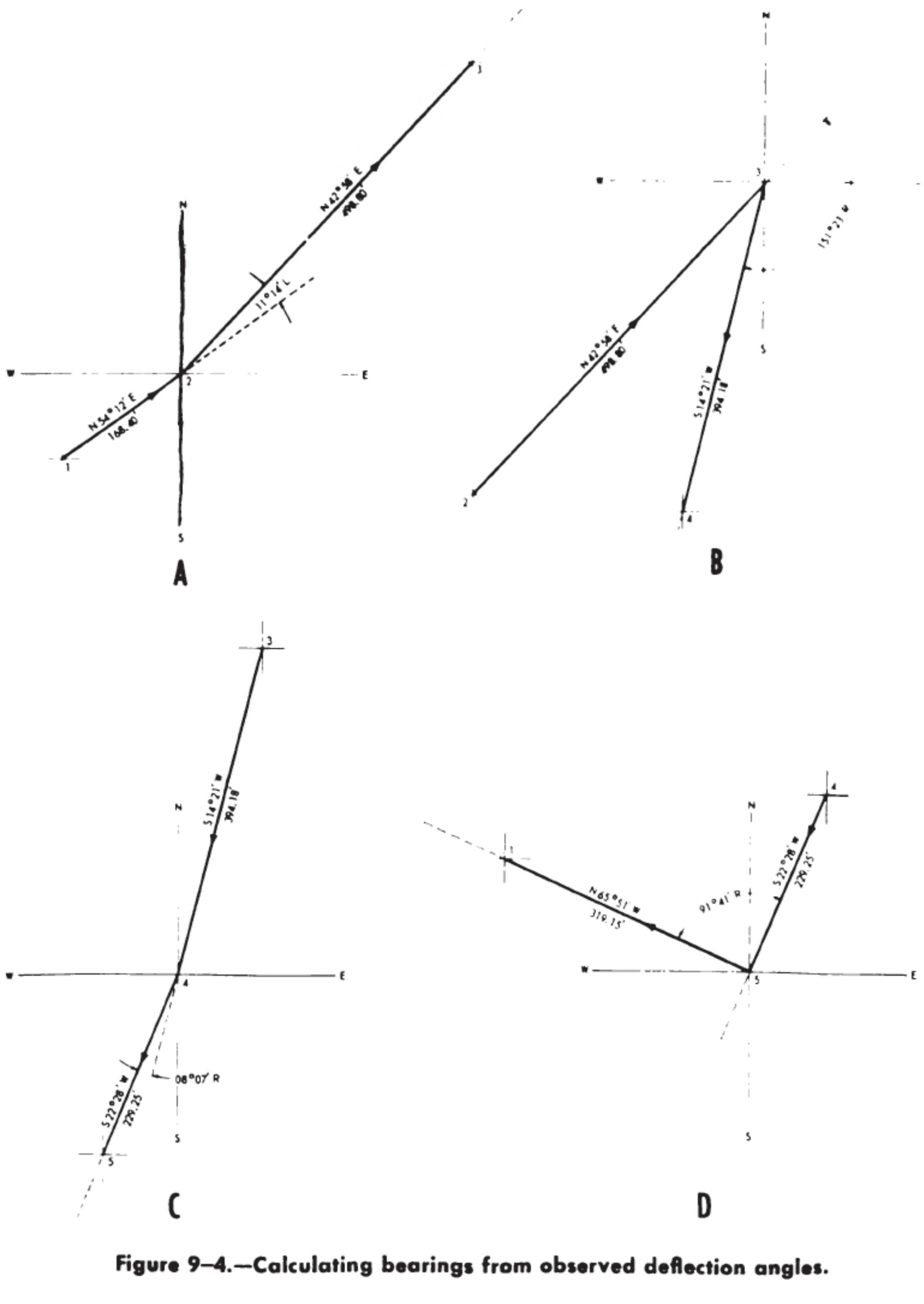


Figure 9–4.—Calculating bearings from observed deflection angles.

from the angle, thus, 151° 23′ − 137° 02′ = S 14° 21′ W, as shown in figure 9–4B.

Station 4–5 has a small right deflection angle which may be added to the bearing for the course for station 3–4, thus, S 14° 21′ W + 08° 07′ = S 22° 28′ W, as shown in figure 9–4C.

For station 5–1, the right deflection angle is again sufficiently large so that it will not fall in the same quadrant as the bearing for the course for station 4–5. But in this case, the angle will fall in a quadrant where measurements are made from the north end of the meridian. Therefore, subtract the angle 91° 41′ R from 180° to get 88° 19′. Then, 88° 19′ or 87° 79′ − 22° 28′ W = N 65° 51′ W, the bearing for the course at station 5–1. Since this agrees with the given bearing for this course, the calculations are correct.

When interior angles have been measured for the traverse, the computations for converting them to bearings are slightly different. Suppose that the observed angles, one known bearing, and distances are given as follows:

Station	Interior Angle	Bearing	Length of Course
A	162° 00′		345 ft.
B	155° 05′		690 ft.
C	68° 25′		1008 ft.
D	77° 22′	N 12° W	1010 ft.
E	77° 23′		344 ft.

First, the bearing must be adjusted according to the formula for polygons, $180°(n-2)$. In this case, $180°(5-2) = 180° \times 3 = 540$. If you add the interior angles for the traverse, you will find that the sum is 540° 10′. Since the 10′ is a plus, it should be subtracted from the angles, and 5′ may be subtracted from the angles for the two stations with the smallest distances.

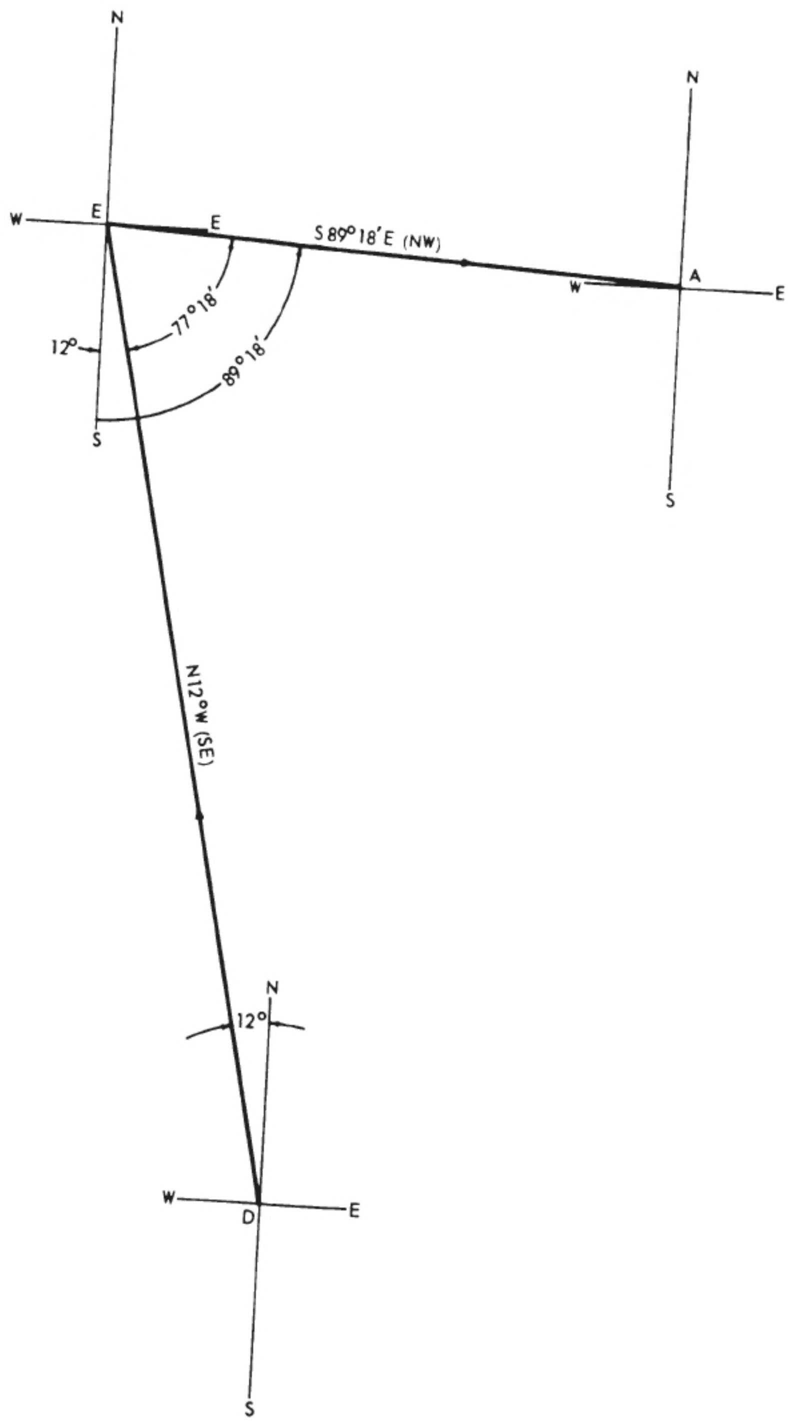


Figure 9–5.—Finding the bearing of a course measured by an interior angle, with the bearing of the preceding course given.

Remember that interior angles are measured by first taking a backsight along the previous course and then swinging the instrument in an arc to take a foresight along the course from the station on which the instrument is set. Therefore, in finding the bearing of a course from the observed interior angle and the bearing of the previous course, the angle should be measured to the left, not from the bearing but from the reverse bearing. For example, the bearing of the course from station D is given as N 12° W. The reverse bearing is S 12° E and S 12° E + 77° 18′ = S 89° 18′ E, as shown in figure 9–5.

Latitudes and Departures

The vertices of the angles of a traverse are referred to as the angle points of the horizontal control. On the ground, the points of the horizontal control form the skeleton of the survey from which objects are located. On the map, these same points become the framework by means of which details are fixed. It is important that horizontal control points be carefully located. Latitudes and departures are often used when a carefully located traverse is desired.

The latitude of any line is the orthographic projection of that line upon a meridian and the departure is its orthographic projection on a parallel. In figure 9–6, AB is the course to be plotted. Let NS represent any meridian and EW represent any parallel. The line AB makes the angle Θ with a line drawn parallel to the meridian. The latitude of AB is AC, its orthographic projection on the meridian, and its departure is AD, its orthographic projection on the parallel. Therefore the latitude of AB is $AC = AB \cos \theta$, and the departure is $AD = AB \sin \theta$. In equation form, this may be written:

$$\begin{aligned} \text{latitude} &= r \cos \theta, \\ \text{departure} &= r \sin \theta, \end{aligned}$$

with r representing the course.

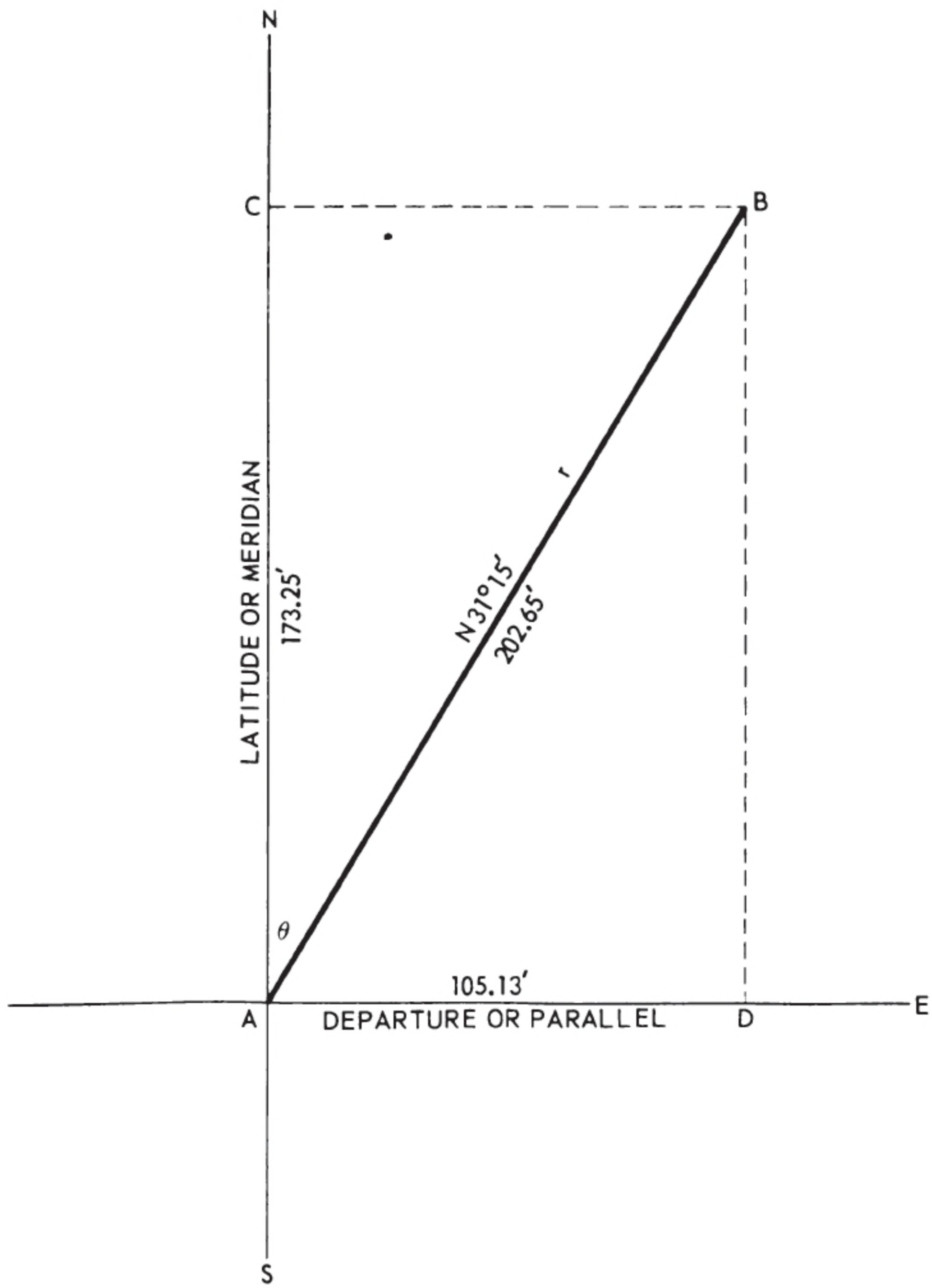


Figure 9–6.—Locating a course by latitude and departure.

For example, suppose the length of a course is 202.65 feet, and the angle which it makes with the meridian is 31° 15′. Using any five place table of natural sines and cosines, look up the sine and cosine for that angle. You will find

$$\sin 31^\circ\ 15' = 0.51877,$$
$$\cos 31^\circ\ 15' = 0.85491.$$

Using these values in the expressions for latitude and departure, you get

$$\text{latitude} = 202.65 \times 0.85491 \doteq 173.25 \text{ feet, and}$$
$$\text{departure} = 202.65 \times 0.51877 = 105.13 \text{ feet.}$$

The laws of logarithms can be used to advantage in computing latitude and departure. The computation for the latitude is tabulated as follows:

$$\begin{array}{lrl}
\log\ \cos & 31^\circ\ 15' = & 9.93192 - 10 \\
\log & 202.65 = & 2.30675 \\
\hline
\log\ \text{latitude} & = & 12.23867 - 10 \\
 & = & 2.23867 \\
\text{latitude} & = & 173.25 \text{ feet.}
\end{array}$$

To find the departure:

$$\begin{array}{lrl}
\log\ \sin & 31^\circ\ 15' = & 9.71498 - 10 \\
\log & 202.65 = & 2.30675 \\
\hline
\log\ \text{departure} & = & 12.02173 - 10 \\
 & = & 2.02173 \\
\text{departure} & = & 105.13 \text{ feet.}
\end{array}$$

Latitudes and departures will be either positive or negative. Latitudes are positive when the course has a northerly bearing. Negative latitudes denote a southerly bearing. Departures are positive for courses having an easterly bearing and negative for a westerly bearing.

In figure 9–7, the departure of AB is easterly and, therefore, positive; the latitude is northerly and positive. The departure of BC is easterly and positive, but the latitude is southerly and negative. For CD, both latitude and departure are negative, since the latitude is southerly and the departure westerly. And for DE, the latitude is positive and the departure negative.

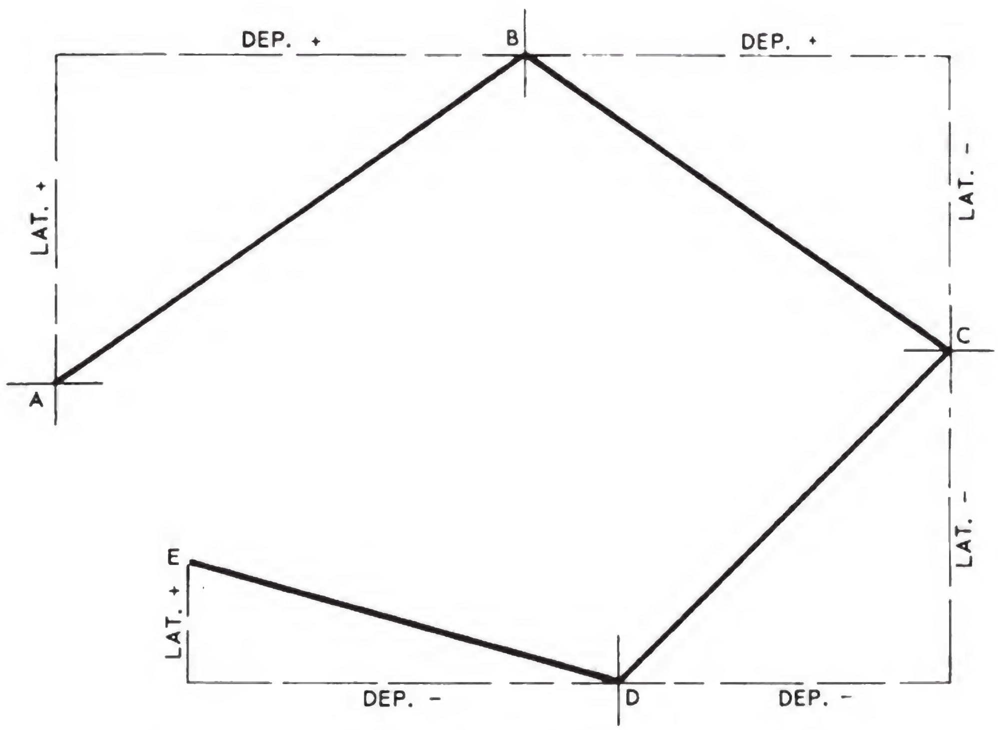


Figure 9–7.—Latitudes and departures may be positive or negative.

By looking at the bearing of the course, you can decide whether you should place a plus sign or a minus sign in front of a latitude or departure. To repeat, for latitude, use a plus sign if the bearing has N in it, a minus sign if it has S. For departure, use a plus sign if the bearing has E in it, and a minus if there is a W.

Now, in order to mathematically correct and balance the traverse, set up a tabulation like that shown in figure 9–8, finding the natural sines and cosines for each bearing and multiplying these by the lengths of the courses to get

Course	Station	Bearing of course	Length of course (feet)	Cosine of bearing	Sine of bearing	Latitude of course	Departure of course
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
	0 + 00						
AB	5 + 84.21	N 3° 45′ 00′ E	584.21	0.99786	0.06540	+ 582.96	+ 38.21
BC	13 + 04.47	S 86° 15′ 10″ E	720.26	0.06535	0.99786	− 47.07	+ 718.72
CD	15 + 16.47	S 10° 49′ 50″ E	212.00	0.98219	0.18790	− 208.22	+ 39.83
DE	18 + 08.78	S 32° 40′ 30″ W	292.31	0.84174	0.53988	− 246.05	− 157.81
EF	20 + 87.31	N 43° 29′ 10″ W	278.53	0.72554	0.68817	+ 202.08	− 191.68
FA	26 + 14.85	S 57° 31′ 00″ W	527.54	0.53705	0.84355	− 283.32	− 445.01
	= 0 + 00						
		Total	2,614.85			+ 0.38	+ 2.26

Figure 9–8.—Finding latitudes and departures for a traverse.

the latitudes and departures. For example, cos 3° 45′ 00″ = 0.99786 and sin 3° 45′ 00″ = 0.06540. When you multiply the cosine of the bearing by the length of the course, you get the latitude. Thus, $0.99786 \times 548.21 = 582.96$, latitude of course. Since the bearing angle has an N in front of it, the latitude is positive and is preceded by a plus sign.

When you multiply the sine of the bearing by the length of the course, you get the departure. Thus, $0.06540 \times 584.21 = 38.21$, departure of the course. Since the bearing has an E following it, the departure is positive and is preceded by a plus sign.

For a perfect polygon, the algebraic sum of the latitudes, as well as the sum of the departures of the sides should be zero. Notice that some of the latitudes given in figure 9–8 are positive and some are negative. To find the sum of the latitudes, first add the numbers with like signs and then find the difference between the sums. Add the negative numbers:

$$\begin{array}{r} 47.07 \\ 208.22 \\ 246.05 \\ 283.32 \\ \hline 784.66 \end{array} \text{ or } -\ 784.66.$$

Add the positive numbers:

$$\begin{array}{r} 582.96 \\ 202.08 \\ \hline 785.04 \end{array} \text{ or } +\ 785.04.$$

Then find the difference between $-\ 784.66$ or $+\ 785.04$. You should have $+\ 0.38$.

In the same way, the algebraic sum of the departures is $+\ 796.76 + (-\ 794.50) = +2.26$. The latitudes and departures do not add to zero. There is an error of $+\ 0.38$

in the sum of the latitudes and an error of + 2.26 in the sum of the departures. The traverse, therefore, is not a perfectly closed polygon.

For a survey which starts and ends at the same point, the courses would form a closed polygon if all lengths and angles could be perfectly measured. But it does not seem possible to avoid some error in field measurements. When courses are plotted from field observations, the end of the survey is not likely to be the same point as the beginning. The starting point and the end point, although they are the same point on the ground, become two different points when plotted on paper. The length of the line joining the start of a survey with the last point of the survey, as plotted from field measurements, is the ERROR OF CLOSURE or linear error of closure. (See fig. 9–9.)

To get the linear error of closure, add the square of the error in the latitudes to the square of the error in the departures, then take the square root of this sum. For

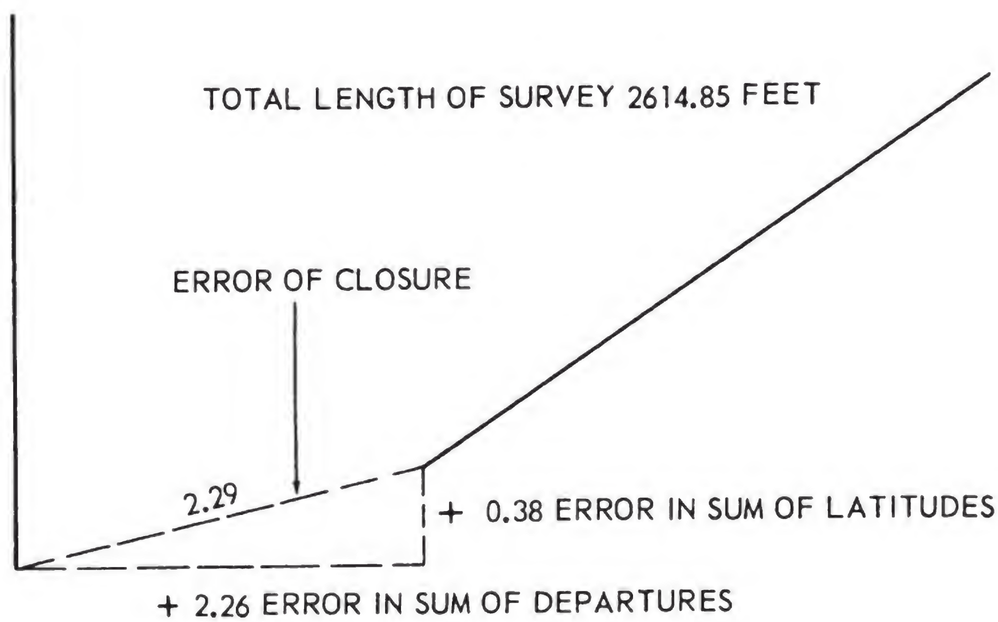


Figure 9–9.—Error of closure of a traverse.

the traverse, you have just been considering, the total error of closure is

$$\sqrt{(0.38)^2+(2.26)^2}=\sqrt{0.14+5.11}=\sqrt{5.25}=2.29 \text{ feet.}$$

As shown in figure 9–9, the error of closure, 2.29, is the length of the hypotenuse of a small right triangle whose legs are 0.38 and 2.26, respectively. You will notice that the procedure used in finding the error of closure is a practical application of the Pythagorean theorem.

The error of closure will be greater in long surveys than in short surveys. Therefore, you need some basis to decide just how accurate a survey is. If you divide the total error of closure by the total length of the courses, you get the PRECISION OF MEASUREMENT.

The total length of the survey in figure 9–8 is 2614.85 feet and the error of closure is 2.29 feet. Usually the precision of measurement is stated in the form of 1 divided by a number. Thus,

$$\frac{2.29}{2614.85}=\frac{1}{\frac{2614.85}{2.29}}=\frac{1}{1137}.$$

The error of closure is roughly 1 foot in 1100 feet.

Even though the traverse is not exactly closed, it must appear closed on a map, if the beginning and end points are the same on the ground. After you find the error of closure, you must make some corrections so that the traverse will form a closed figure according to geometry. Applying corrections to the latitudes and departures of the courses of a survey is called BALANCING THE SURVEY. There are several rules for making the corrections to balance a survey. One of these is the COMPASS RULE.

The compass rule states that the correction to be applied to the latitude or departure of any course is to the total error in the sum of latitudes or departures as the length of the course is to the total length of the traverse.

This relationship can be expressed in the following proportion:

$$\frac{\text{Correction}}{\text{Total error}} = \frac{\text{Length of course}}{\text{Total length of traverse}}$$

or

$$\text{Correction} = \frac{\text{Total error} \times \text{length of course}}{\text{Total length of traverse}}.$$

The tabulation in figure 9–10 shows the values for the latitudes and departures for the same traverse as that shown in figure 9–8. In this example, the total error in the sum of the latitudes is 0.38 and the error in the sum of the departures is 2.26. The length of the survey is 2,614.85 feet.

From these values, you get

$$\text{Correction Factor for latitudes} = \frac{0.38}{2614.85} = 0.000145,$$

and

$$\text{Correction factor for departures} = \frac{2.26}{2614.85} = 0.000864.$$

In columns 3 and 4 in figure 9–10, you see the corrections for the latitudes and departures. To obtain these, multiply the length of each course by the correction factors. For example, $584.21 \times 0.000145 = 0.08$ and $584.21 \times 0.000864 = 0.50$. Because 0.08 and 0.50 are corrections, they must have signs opposite those of the errors in the latitudes and departures. That is, since they represent the excess in distance which causes the error of closure, they must be subtracted from the latitude and departure. This is true for all the other corrections in columns 3 and 4. If the errors had been minus, the corrections would have been a plus.

Now add algebraically the corrections to the latitudes and departures to get the adjusted latitudes and departures in columns 5 and 6. Remember that, when you add numbers with unlike signs, you actually find their differ-

Latitude	Departure	Correction to latitude	Correction to departure	Adjusted latitude	Adjusted departure
(1)	(2)	(3)	(4)	(5)	(6)
+ 582.96	+ 38.21	− 0.08	− 0.50	+ 582.88	+ 37.71
− 47.07	+ 718.72	− 0.10	− 0.62	− 47.17	+ 718.10
− 208.22	+ 39.83	− 0.03	− 0.18	− 208.25	+ 39.65
− 246.05	− 157.81	− 0.04	− 0.25	− 246.09	− 158.06
+ 202.08	− 191.68	− 0.04	− 0.24	+ 202.04	− 191.92
− 283.32	− 445.01	− 0.08	− 0.46	− 283.40	− 445.47
+ 0.38	+ 2.26	− 0.37	− 2.25	+ 0.01	+ 0.01

Figure 9–10.—Adjusting latitudes and departures.

ence and keep the sign of the numerically larger number. In the first row, you should have

$$+\ 582.96 + (-\ 0.08) = +\ 582.88,$$

and

$$+\ \ 38.21 + (-\ 0.50) = -\ 37.71.$$

There is also a simple graphical method for making traverse adjustments, which requires no mathematical computations. The traverse *ABCDA′*, shown in figure 9–11, has been plotted by angles and distances, and there is an error of closure shown as *AA′*. To adjust this traverse graphically, draw a straight line, as shown below, representing the total measured distance of the traverse.

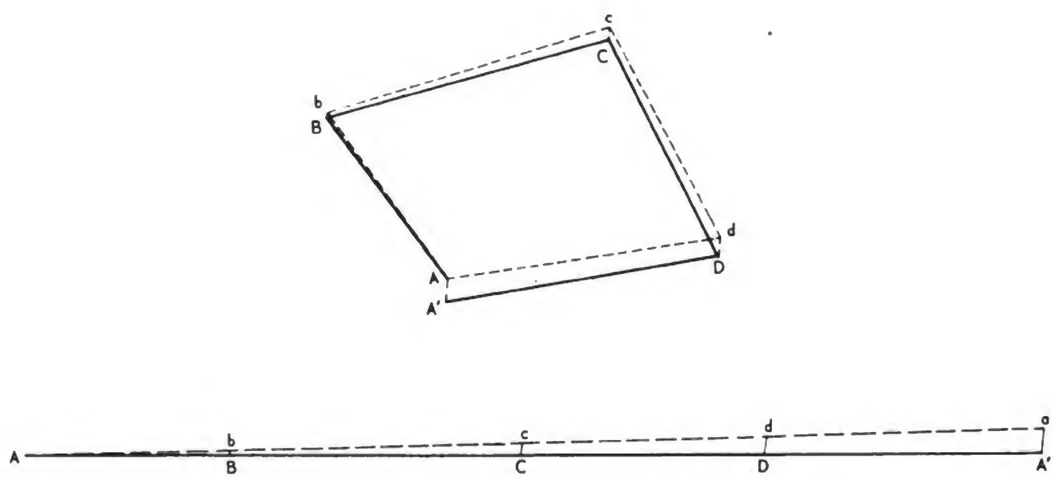


Figure 9–11.—Graphical method of closing a traverse.

On this line, plot points *B*, *C*, and *D*. Now construct a line, shown as *A′a*, which is parallel to the error of closure *AA′* of the plotted traverse, and the same length, or equal to it at a convenient scale. Draw a second straight line *Aa*, and construct lines, which are parallel to *A′a*, from the plotted points *B*, *C*, and *D* to this second line. These lines represent the correction that should be made at *B*, *C*, and *D* on the original traverse in order to close it, as shown by the dotted lines the drawing of the traverse.

The correction triangle may be constructed with the long lines AA' and Aa to one scale and the error of closure drawn to a larger scale, if desired.

Cut and Fill

The principles of computing earthwork quantities are also used in computing volumes of stock piles of crushed stone, gravel, sand, coal, ore, and the like, and in computing volumes of reservoirs. A knowledge of earthwork volumes is one of the items necessary in estimating the cost of such construction projects as pipe lines, sewers, cellars, borrow pits, grading, highways, and railroads.

The methods used in determining the volumes will vary somewhat with different kinds of work, depending upon the degree of accuracy required. For example, since the unit of cost of the common excavation (earth) is relatively low, it is not practical to compute the volumes with any great degree of precision. However, in computing masonry volumes, you must work to closer precision because the pouring of a cubic yard of concrete costs many times more than the hauling of a cubic yard of earth. Thus, for earth excavations, you will probably use the average end-area formula; for masonry volumes, you will use the more accurate prismoidal formula.

It is important in earthwork computations to make allowance for shrinkage and small factors of the excavated material. Excavated material is usually classified as common excavation (earth), loose rock, and solid rock. When earth is excavated and moved, the final volume is sometimes less than the space which the earth occupied in its original location. The loss between the original volume in cut and the final volume in fill is called shrinkage. The reduction in volume may be due to the method of placing the material, the degree of compaction, the amount of water in the material, the type of soil, and the loss of material during transportation. A 10–15 percent allowance is usually made for shrinkage. This means that if the computed volume of a fill is 50 cubic yards, actually 55 to 60 cubic yards of the excavated earth will be re-

quired to fill to grade. Do not confuse shrinkage with subsidence. SUBSIDENCE is settlement or volume loss due to unstable foundation conditions that might occur when heavy fill is placed over swampy soil.

Rock fills occupy more volume in the fill than the material occupied before excavation. This increase in volume is called SWELL. Because of the voids left between rocks, the swell may be as high as 25 to 40 percent. If the fill is mostly earth, with only a few large rocks, the swell is usually disregarded.

One of the purposes of earthwork computations is to determine how much cut or fill will be required. However, before you can compute volumes, you must determine the area between the finished roadbed and ground line at each cross section. This area is sometimes referred to as an end area. If the end areas of two successive sections are known, the volume of earth (cut or fill) to be moved to bring the ground to the proper grade between these two sections may be computed.

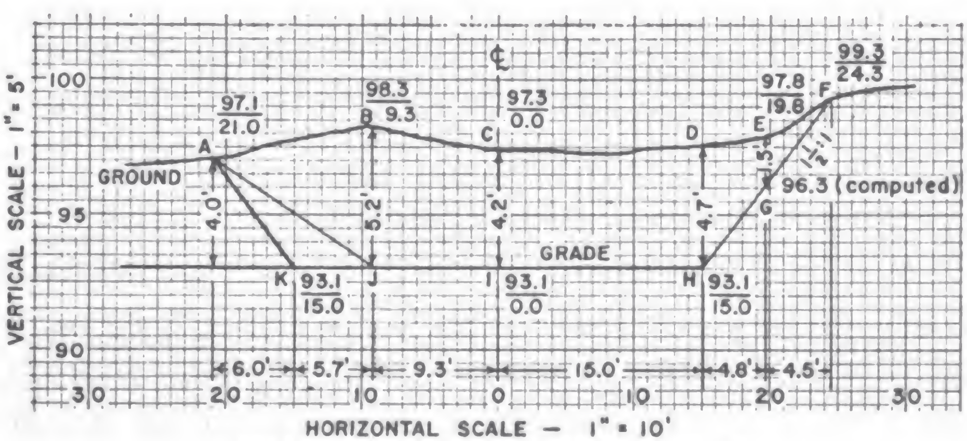
Cross section areas for construction earthwork volumes are usually determined by one of the following methods: by counting squares, by the geometry of trapezoids and triangles, by using a planimeter, by the stripper method, by the double-meridian-distance (D. M. D.) method, or by the coordinate method. The degree of accuracy desired, the shape of the particular cross section, and personal preference, will determine the specific method to be used. For example, if the cross section reveals that the ground is level or regular, it may be advisable to compute the end area by the geometric method. For irregular cross section shapes, you may use the planimeter. Where both cut and fill areas occur simultaneously in a cross section, it is necessary to compute the area of each, separately.

The counting-the-squares and the stripper methods give only approximate results; the other methods give results as accurate as the cross section data will permit. The counting-the-squares method and the geometric method will be given here. The use of a planimeter is discussed

in *Draftsman 3*, NavPers 10471. The D. M. D. and coordinate methods are discussed in *Surveyor 1 & C*, NavPers 10633–A.

COUNTING-THE-SQUARES METHOD.—Because the cross profile of the ground line and the cross section of the finished roadbed, including the side slopes at each station, are all drawn to the same predetermined scale, you can quickly compute the end areas by counting the total number of squares that are included within the boundary lines of the cross section. The total number of counted squares is then multiplied by the number of square feet represented by a single square. For example, the cross section shown in figure 9–12 encloses 350 individual $\frac{1}{10}$-inch squares. Because the horizontal scale in figure 9–12 is 1″ equals 10′, and the vertical scale is 1″ equals 5′, each $\frac{1}{10}$″ square represents 1′ horizontally and 6″ vertically. Each square is one-half a square foot in area. The approximate area of the cross section is $350 \times \frac{1}{2}$ or 175 square feet.

GEOMETRIC METHOD.—The geometric method is sometimes called the trapezoidal method. To compute the area of a cross section by this method, subdivide the area into simple geometrical figures, such as triangles, rectangles, and trapezoids, whichever is most convenient for the par-



AREA = 175.0 SQ FT BY COUNTING SQUARES
AREA = 170.6 SQ FT BY TRAPEZOIDS AND TRIANGLES

Figure 9–12.—Area of an irregular cross section.

ticular cross section. Calculate the area of each figure according to the scale (to which the cross section is drawn), and total the results. There is no set rule for subdividing the cross section; the individual doing the computing uses his own judgment in selecting those subdivisions which will simplify the calculations and produce the most accurate result. The following computations are based on the cross section shown in figure 9–12. The formula for the area of a triangle is

$$A = \frac{bh}{2}.$$

The formula for the area of a trapezoid is

$$A = \frac{h\ (b_1 + b_2)}{2}$$

in which A represents the area; b, b_1 and b_2 represent the length of the bases; and h represents the perpendicular distance, or height, between parallel bases.

Note that the computation is simplified by adding all the numerical products for triangles and trapezoids together and then dividing the total by 2. Thus,

2A of triangle EFG	=	5.7×4.0	=	22.8
2A of triangle AJK	=	$5.2\ (5.7 + 6.0)$	=	60.8
2A of triangle ABJ	=	$4.8\ (4.7 + 1.5)$	=	29.8
2A of trapezoid $BCIJ$	=	$9.3\ (5.2 + 4.2)$	=	87.4
2A of trapezoid $CDHI$	=	$15.0\ (4.2 + 4.7)$	=	133.5
2A of trapezoid $DEGH$	=	1.5×4.5	=	6.8
Total (double area of AFHK)			=	341.1
Area of the cross section	=	$341.1 \div 2$	=	170.6 sq. ft.

The computation of earthwork volumes is basically a problem in solid geometry. In volume computations, consider the earth between each cross section as a solid prismoid shape. Knowing the area of, and the distance between, each cross section, you can compute the volumes. Volumes may be computed by using the average-end-area

formula, the prismoidal formula, or earthwork tables.

The AVERAGE-END-AREA-METHOD is the simplest and most commonly used method of determining the volume between cross sections or end areas. The end-area formula assumes that the volume contained between successive end areas is the average of the two end areas multiplied by the perpendicular distance between them. This relationship is expressed by the formula:

$$V = \frac{(A_1 + A_2)}{2} l$$

in which A_1 and A_2 represent the respective end areas in square feet, l the distance between end areas in feet, and V the volume in cubic feet. (See fig. 9–13.)

Volumes computed by the end-area formula are approximate and are usually in excess of the actual volumes. The formula is exact only when A_1, and A_2, are of the same shape and area. The greater the difference in shape between the two areas, the greater the error in volume, which may be as great as 50 percent. In common excavations where the unit cost is relatively low, the end-area formula is consistent with the precision of the field methods in general use, and has become the standard earthwork formula. In computing masonry volumes, greater precision is required. For such work, use the more accurate prismoidal formula.

PRISMOIDAL FORMULA.—The volume of a prismoid is expressed by the formula:

$$V = \frac{l}{6} (A_1 + 4A_m + A_2),$$

in which V represents the volume in cubic feet, A_1 and A_2 the end areas in square feet, A_m the area in square feet of the section midway between A_1 and A_2, and l the perpendicular distance between the end areas in feet. If you look at figure 9–13, you will see that A_m is not the average of A_1 and A_2, but a separate section.

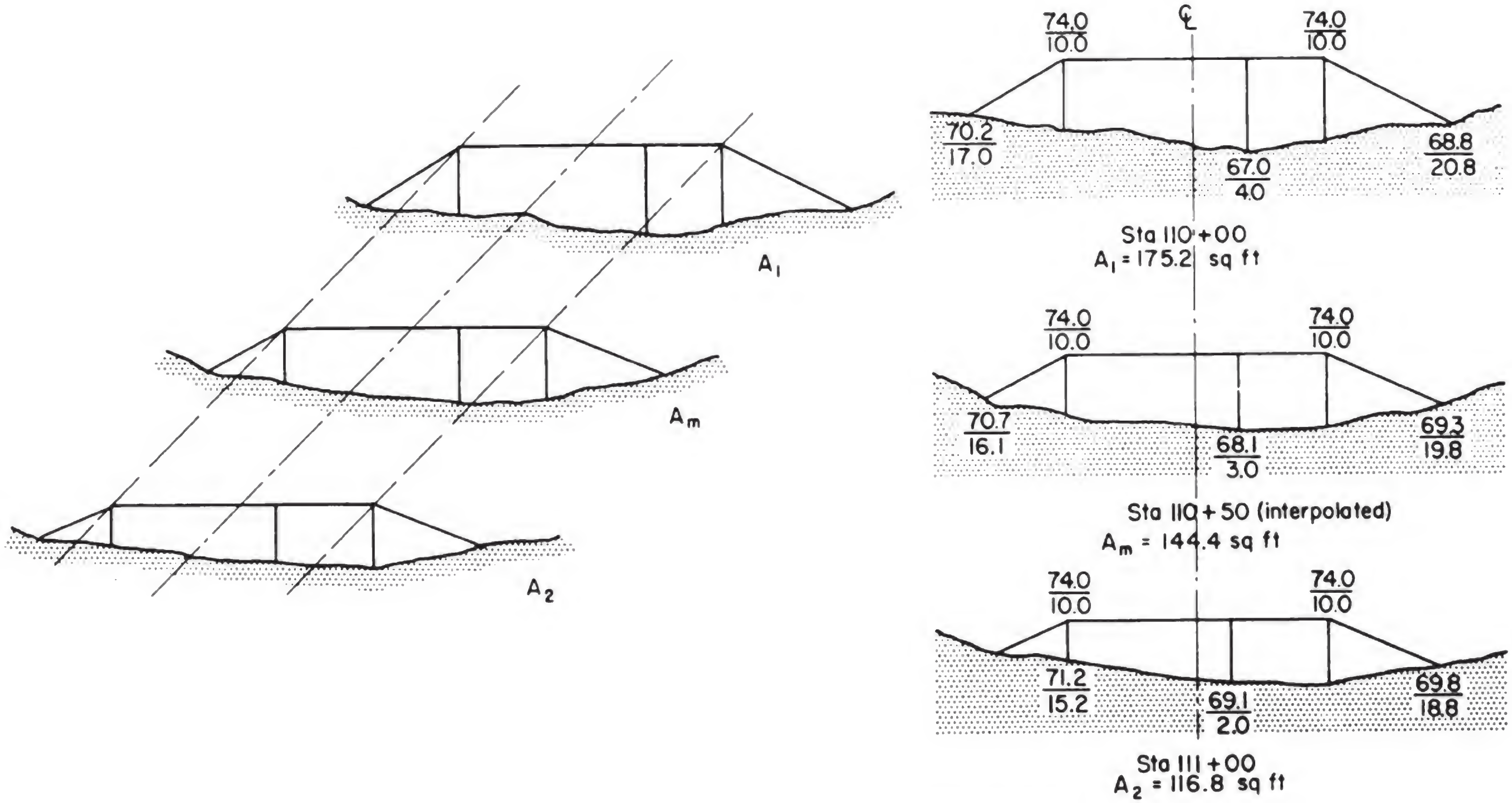


Figure 9-13.—Areas for use in the prismoidal formula.

The computed end area A_1 at station $110 + 00$ is 175.2 square feet; end area A_2 at station $111 + 00$ is 116.8 square feet; while area A_m at station $110 + 50$ is 144.4 square feet. The coordinates of the cross section at station $110 + 50$ are determined by interpolating the ordinates and abscissas of A_1 and A_2. For example, the mean value, 70.7, of the ordinate at the left slope and ground intersection in cross section A_m equals $\frac{1}{2}$ $(70.2 + 71.2)$. The mean abscissa 16.1 is found by taking $\frac{1}{2}$ $(17.0 + 15.2)$. The value of coordinates $\frac{68.1}{3.0}$ and $\frac{69.3}{19.8}$ are calculated by the same procedure. The values $\frac{74.0}{10.0}$ represent the finished roadbed and are the same for all three sections. Substituting in the prismoidal formula, the volume of earthwork between stations $110 + 00$ and $111 + 00$ is:

$$V = \frac{100}{6} (175.2 + (4 \times 144.4) + 116.8)$$

$$= 14{,}493 \text{ cubic feet, divided by } 27$$

$$= 537 \text{ cubic yards.}$$

Note that the average-end-area method gives 541 cubic yards for this same volume; or 0.74 percent greater value, an error which is negligible for practical purposes.

EARTHWORK TABLES.—In extensive construction operations, many routine volume computations may be simplified by the use of tables for volumes. Such useful tables are available in many engineer reference handbooks, manuals, and civilian texts. The common form of tables are those for level sections, 3-level sections, triangular prisms, and prismoidal corrections. In the absence of reference tables, you can compile your own simple tables which meet the job requirements and which eliminate repetition of routine computations.

Horizontal Curves

A railroad or a highway consists mainly of straight portions (tangents) connected by circular curves. Occa-

sionally, on railroads or on modern highways, these elements are connected by spiral transition curves. Circular curves may be simple, compound, or reversed. A simple curve consists of an arc of a single circle which connects the two tangents. Curves are designated in terms of the degree (D) of curve or in terms of the radius (R) of curve. The degree may be defined either as the central angle subtended by a CHORD of 100 feet, or as the central angle subtended by an ARC of 100 feet. For railway curves, the chord definition is always used. Either may be used for highways but the arc definition is slowly replacing the chord.

The point where the curve starts (towards station $0 + 00$) is the *P. C.* and the point where the curve ends is the *P. T.* Any point on the curve is the *P. O. C.* The intersection of the tangents extended is the *P. I.* The angle of deflection at the point where the tangents intersect is the angle I. The angle between the radii at the center of the curve is the central angle (Δ). Angle I is always equal to this central angle (Δ) because the tangent to a circle is always perpendicular to the radius drawn to the point of contact. The distance from the *P. I.* to either the *P. C.* or the *P. T.* is the tangent distance (T). The straight line distance between the *P. C.* and the *P. T.* is the long chord (C). The long chord subtends the entire curve and is referred to as the long chord (C) in order to distinguish it from the shorter chords and subchords used in setting stations on the curve. The distance from the *P. I.* to the midpoint of the arc is the external distance (E), sometimes called the external secant. The distance from the midpoint of the arc to the midpoint of the long chord (C) is the middle ordinate (M). The distance along the arc from the *P. C.* to the *P. T.* is the length of the arc (L).

Curves may be computed mathematically, but work can often be greatly simplified by referring to tables found in handbooks. Both methods arrive at approximately the same results. The following formulas indicate the relationships existing between the various elements

of a curve. Given any two factors in any formula, you may easily calculate the third unknown quantity. Refer to figure 9–14 and figure 9–15.

$$T = R \tan \tfrac{1}{2} I.$$
$$C = 2R \sin \tfrac{1}{2} I.$$
$$M = R\,(1 - \cos \tfrac{1}{2} I).$$
$$E = T \tan \tfrac{1}{4} I.$$
$$L = 100 \frac{I}{D}.$$
$$D = \frac{100\, I}{L}$$
or
$$D = \frac{100\, \Delta}{L}.$$

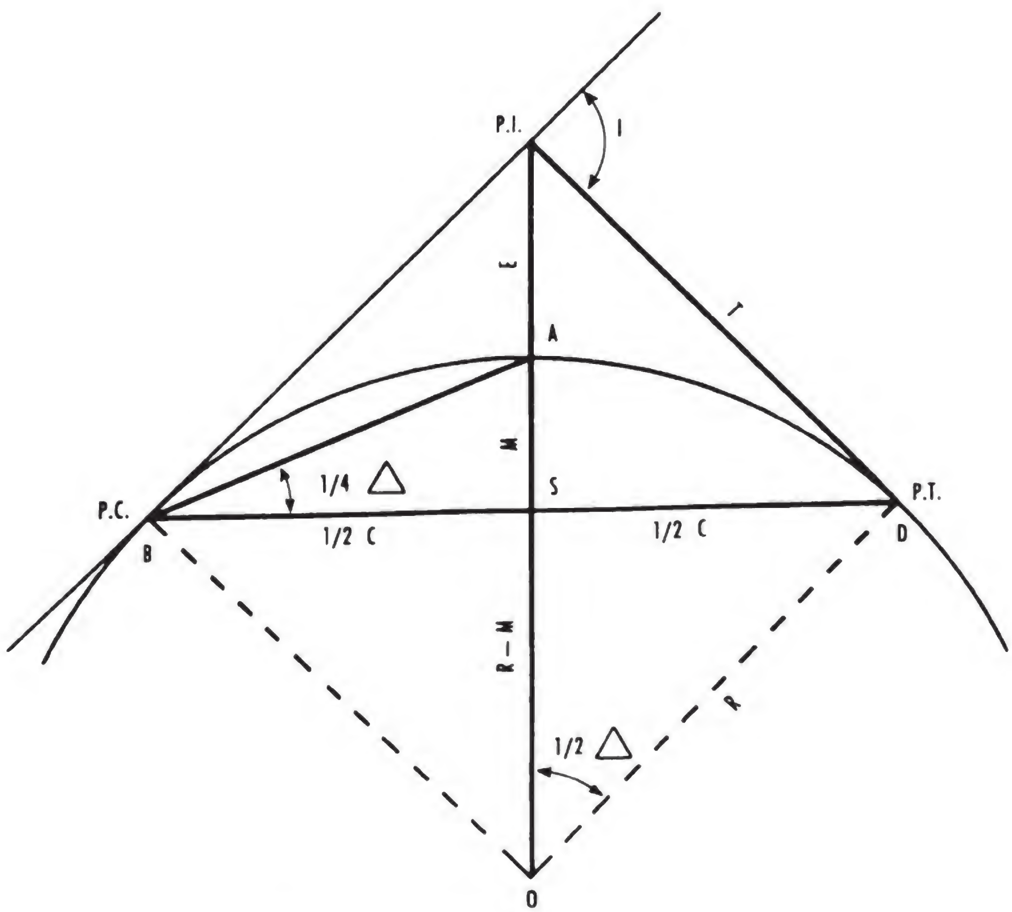


Figure 9–14.—Elements of a circular curve.

$$I = \frac{DL}{100}.$$

$$R = \frac{5729.58}{D} \text{ (using the arc definition).}$$

$$R = \frac{50}{\sin \frac{1}{2} D} = 50 \csc \tfrac{1}{2} D = 5729.65 \text{ feet}$$

(using the chord definition).

Because of the difference in length between the arc and chord subtended by any given degree of curve, it is important to know which definition is being used before you select tables of computed quantities. Refer to figure 9–16 which is a table of corrected chord lengths for the degree of curve defined as an angle subtended by an arc of 100 feet. Note that for an 18° curve, the

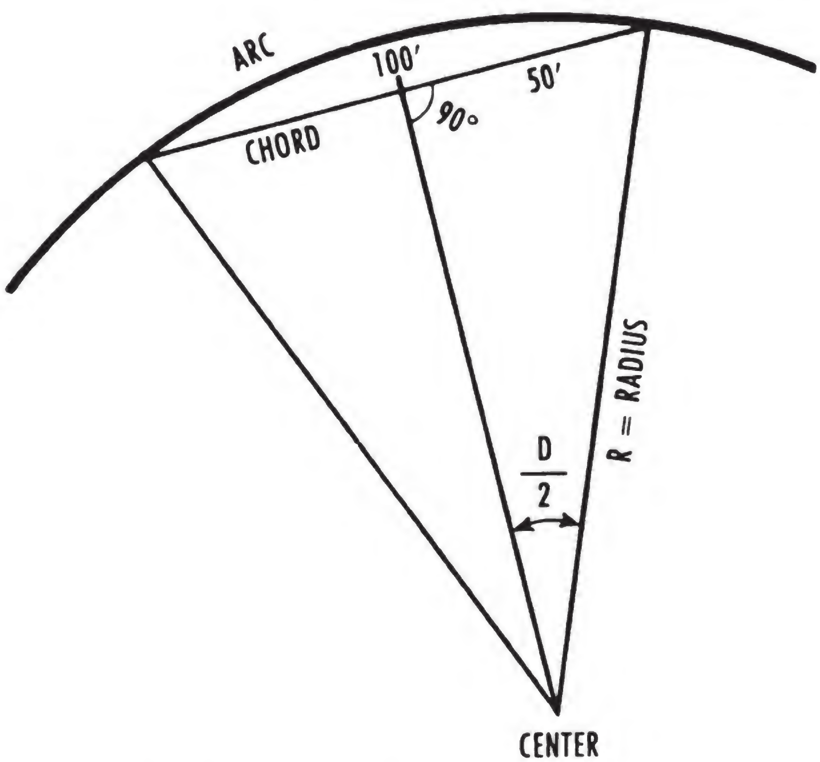


Figure 9–15.—Degree of curve (chord definition).

corrected chord length for a 25-foot arc is 24.99 feet; for a 50-foot arc, the corrected chord length is 49.95 feet; for a 100-foot arc, the corrected chord length is 99.59 feet.

Now refer to figure 9–17 which shows the radius of a circle for various degrees of curve based on the chord definition. Figure 9–17 also shows the cosecant of ½ the degree of curve and the radius corresponding to degree of curve from 1 to 20. Notice that, as the degree of curve is doubled, the radius of the circle is approximately half as great. Keep in mind that the degree of curve (D), according to the chord definition, assumes that the chord is exactly 100 feet long. The fourth column in figure 9–17

Degree of curve (degrees)	Radius $= 5{,}729.58 \frac{(I)}{D}$	Chord for 25 feet of arc	Chord for 50 feet of arc	Chord for 100 feet of arc
1	5, 729. 58	25. 00	50. 00	100. 00
2	2, 864. 79	25. 00	50. 00	100. 00
3	1, 909. 86	25. 00	50. 00	99. 99
4	1, 432. 40	25. 00	50. 00	99. 98
5	1, 145. 92	25. 00	50. 00	99. 97
6	954. 93	25. 00	50. 00	99. 95
7	818. 51	25. 00	50. 00	99. 94
8	716. 20	25. 00	49. 99	99. 92
9	636. 62	25. 00	49. 99	99. 90
10	572. 96	25. 00	49. 98	99. 87
12	477. 46	25. 00	49. 98	99. 82
14	409. 26	25. 00	49. 97	99. 75
16	358. 10	25. 00	49. 96	99. 68
18	318. 31	24. 99	49. 95	99. 59
20	286. 48	24. 99	49. 94	99. 49
22	260. 44	24. 99	49. 92	99. 39
24	238. 73	24. 99	49. 91	99. 27

Figure 9–16.—Radii and corrected chord lengths for degree of curve defined as an angle subtended by an arc of 100 feet.

Degree of curve = D	csc ½D	Radius = 50 csc ½D (feet) 50 sine ½D	Length of arc for 100′ chord	Long chords			
				2 sta.	3 sta.	4 sta.	5 sta.
Degrees							
1......	114.593	5,729.65	100.001	199.99	299.97	399.92	499.85
2......	57.299	2,864.93	100.005	199.97	299.88	399.70	499.39
3......	38.202	1,910.08	100.011	199.93	299.73	399.32	498.63
4......	28.654	1,432.69	100.020	199.88	299.51	398.78	497.57
5......	22.926	1,146.28	100.032	199.81	299.24	398.10	496.20
6......	19.107	955.37	100.046	199.73	298.90	397.26	494.53
7......	16.380	819.02	100.062	199.63	298.51	396.28	492.57
8......	14.336	716.78	100.081	199.51	298.05	395.14	490.31
10......	11.474	573.69	100.127	199.24	296.96	392.42	484.90
12......	9.5668	478.34	100.183	198.90	295.63	389.12	478.34
14......	8.2055	410.28	100.249	198.51	294.06	385.22	470.65
16......	7.1853	359.27	100.326	198.05	292.25	380.76	461.86
18......	6.3925	319.62	100.412	197.54	290.21	375.74	452.02
20......	5.7588	287.94	100.510	196.96	287.94	370.17	441.15

Figure 9–17.—Radius of circle for various degrees of curve based on chord definition.

gives the corrected length of the subtended arc for each of the degrees of curve.

Computed values of the long chord, the middle ordinate, the external secant, and the tangent length for central angles up to about 120° can be found in handbooks. Often they are shown for a 1° curve and are listed as functions of a 1° curve. The corresponding functions for any other degree of curve can be found from them. Circular arcs having the same central angle are to each other as the radii of the circles. Therefore, when the arc definition of degree of curve is being used, the function (tangent, external, long chord, or middle ordinate) desired is found by dividing the 1° curve function by the degree of curve.

As an example, figure 9–18 shows tangents and externals for 1° curves. For a central angle of 60°, we find the following values: $T = 3308.0$ and $E = 886.4$.

To find the length of the tangent and the external

Central angle (degrees)	Tangent	External	Central angle (degrees)	Tangent	External
1	50. 00	0. 22	25	1270. 2	139. 11
2	100. 01	. 87	30	1535. 3	202. 12
3	150. 04	1. 96	35	1806. 6	278. 1
4	200. 08	3. 49	40	2085. 4	367. 7
5	250. 16	5. 46	45	2373. 3	472. 1
6	300. 28	7. 86	50	2671. 8	592. 3
7	350. 44	10. 71	55	2982. 7	729. 9
8	400. 66	13. 99	60	3308. 0	886. 4
10	501. 28	21. 89	70	4011. 9	1265. 0
12	602. 21	31. 56	80	4807. 7	1749. 9
14	703. 51	43. 03	90	5729. 7	2373. 3
16	805. 25	56. 31	100	6828. 3	3184. 1
18	907. 49	71. 42	110	8182. 8	4259. 7
20	1010. 3	88. 39	120	9924. 0	5729. 7

Figure 9–18.—Tangents and externals for 1° curves.

secant for a 10° curve divide these values by 10. We then obtain: $T = 330.8$ feet and $E = 88.64$ feet. These are the exact values for a 10° curve being laid out by the arc definition.

Let us see that these values agree with those obtained by substituting directly in the formulas. We have found that the tangent length in terms of the central angle is given by

$$T = R \tan \tfrac{1}{2} \mathrm{I}.$$

From figure 9–16, the radius of a circle for a 10° curve (arc definition) is 572.96. Half the central angle is 30°. Then by substitution in the formula, we have

$$\begin{aligned} T &= 572.96 \tan 30^\circ \\ &= 572.96\ (0.57735) \\ &= 330.80 \text{ feet.} \end{aligned}$$

Likewise, using the value of T just found. we obtain for the external distance

$$
\begin{aligned}
E &= T \tan \tfrac{1}{4} I \\
&= 330.80 \tan 15^\circ \\
&= 330.80\ (0.26795) \\
&= 88.64 \text{ feet.}
\end{aligned}
$$

If the chord definition is being used in the curve layout, then the values of T and E will be slightly longer. Figure 9–19 shows corrections to be added. Adding the corrections as taken from the tables, we may write

$$
\begin{array}{rr}
330.80 & 88.64 \\
0.42 & 0.11 \\
\hline
T = 331.22 \text{ feet.} & E = 88.75 \text{ feet.}
\end{array}
$$

Checking again with the values as found from the formulas, we use the value 573.69 taken from figure 9–17 for the radius of the circle corresponding to a 10° curve (chord definition). The results of substitution are

$$
\begin{aligned}
T &= 573.69 \tan 30^\circ \\
&= 573.69\ (0.57735) \\
&= 331.22 \text{ feet,}
\end{aligned}
$$

and

$$
\begin{aligned}
E &= 331.22 \tan 15^\circ \\
&= 331.22\ (0.26795) \\
&= 88.75 \text{ feet.}
\end{aligned}
$$

Curves are usually laid out in the field by deflection angles. That is, points are set by angles laid off from the $P.\ C.$ and chord lengths are taped from the preceding points. Unless obstructions interfere, curves are run in

FOR TANGENTS ADD

Central angle (degrees)	Degree of curve								
	5°	10°	15°	20°	25°	30°	40°	50°	60°
10	0. 03	0. 06	0. 09	0. 13	0. 16	0. 19	0. 25	0. 31	0. 38
20	. 06	. 13	. 19	. 26	. 32	. 39	. 51	. 65	. 79
30	. 10	. 19	. 29	. 39	. 49	. 59	. 79	. 99	1. 20
40	. 13	. 26	. 40	. 53	. 67	. 80	1. 06	1. 34	1. 64
50	. 17	. 34	. 51	. 68	. 85	1. 02	1. 36	1. 72	2. 10
60	. 21	. 42	. 63	. 84	1. 05	1. 27	1. 71	2. 17	2. 60
70	. 25	. 51	. 76	1. 02	1. 28	1. 54	2. 06	2. 60	3. 16
80	. 30	. 61	. 91	1. 22	1. 53	1. 84	2. 46	3. 10	3. 78
90	. 36	. 72	1. 09	1. 45	1. 83	2. 20	2. 94	3. 70	4. 50
100	. 43	. 86	1. 30	1. 74	2. 18	2. 62	3. 50	4. 40	5. 37
120	. 62	1. 25	1. 93	2. 52	3. 16	3. 81	5. 11	6. 44	7. 80

FOR EXTERNALS ADD

Central angle (degrees)	Degree of curve								
	5°	10°	15°	20°	25°	30°	40°	50°	60°
10	0. 001	0. 003	0. 004	0. 006	0. 007	0. 008	0. 011	0. 014	0. 017
20	. 006	. 011	. 017	. 022	. 028	. 034	. 045	. 057	. 070
30	. 013	. 025	. 038	. 051	. 065	. 078	. 103	. 129	. 170
40	. 023	. 046	. 070	. 093	. 117	. 141	. 203	. 265	. 290
50	. 037	. 075	. 116	. 151	. 189	. 227	. 305	. 384	. 467
60	. 056	. 112	. 168	. 225	. 283	. 340	. 457	. 575	. 697
70	. 080	. 159	. 240	. 321	. 403	. 485	. 652	. 819	. 994
80	. 110	. 220	. 332	. 445	. 558	. 671	. 903	1. 13	1. 38
90	. 149	. 299	. 450	. 603	. 756	. 910	1. 22	1. 54	1. 87
100	. 200	. 401	. 604	. 809	1. 01	1. 22	1. 64	2. 06	2. 50
120	. 360	. 721	1. 08	1. 45	1. 82	2. 19	2. 95	3. 72	4. 50

Figure 9–19.—Corrections to be added to tangents and external distances for curves laid out by chord definition.

from *P. C.* to *P. T.* with the transit at *P. C.* (See fig. 9–20.) Deflection angles for 100-foot lengths are multiples of $\frac{1}{2}D$. Any chord less than 100 feet is called a subchord. Some handbooks recommend 100-foot chords up to 8° curves, 50-foot subchords up to 16°, 25-foot subchords up to 32°, and 10-foot subchords above 32° curves.

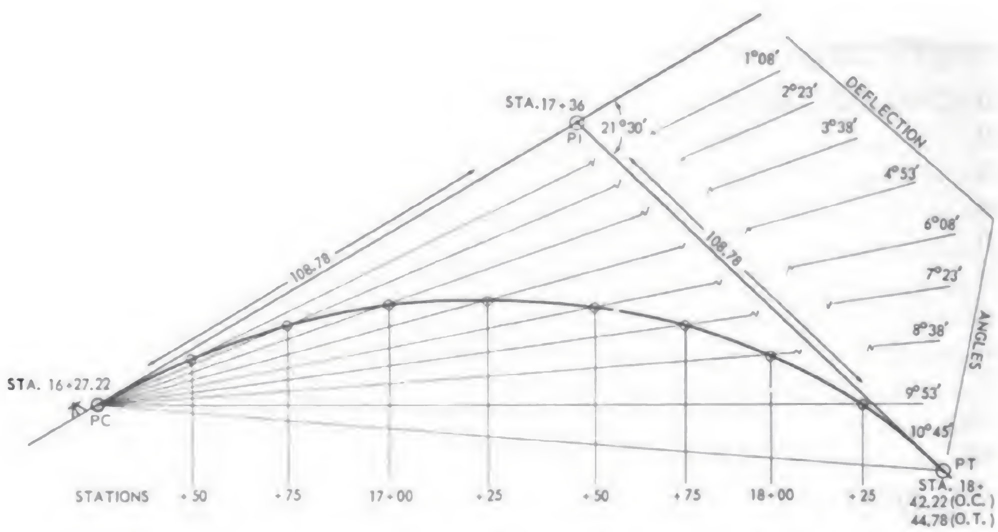


Figure 9–20.—Showing 25-foot chords and curve layout.

The deflection angle at *P. I.* in figure 9–20 is 21° 30′, and the station is 17 + 36.00. It has been decided to use a 10° curve. From this data it is possible to find the other necessary angles and distances.

By substituting in the formula $T = R \tan \frac{1}{2} I$, you find that the tangent distance is 108.78 feet. Subtracting this figure from the station at *P. I.* gives the station at *P. C.* as 16 + 27.22, and adding it to the station at *P. I.* gives the station at *P. T.* as 18 + 44.78. Next calculate the length of the arc between *P. C.* and *P. T.* Substituting in the formula $L = \frac{I}{D} 100$, you find that the length of the arc is 215.00 feet. To set the *P. T.* on the arc, add

215.00 to the *P. C.* to get 18 + 42.22 (*O. C.*). Thus *P. T.* is both 18 + 42.44 (*O. C.*) and 18 + 44.78 (*O. T.*).

The subchords are to be 25 feet long. In setting stations by the chord method, it is desirable to begin at an even station. The next nearest even station is 16 + 50, referred to as a PLUS distance. Thus, the first subchord will be 22.78 feet long. Because the curve is relatively flat and the subchords short, there will not be an appreciable difference between the chord length and the arc length. Therefore, the procedure for setting stations by either chord or arc definition is essentially the same in this problem, and either C or L may be used in the deflection angle formula. Thus,

$$\begin{aligned}\text{Deflection angle} &= \tfrac{1}{2}\, D\, \frac{(C \text{ or } L)}{100}\\ &= \tfrac{1}{2}\,(10)\,\frac{22.78}{100}\\ &= \frac{2.28}{2}\\ &= 1.14 \text{ or } 1^\circ\, 8''.\end{aligned}$$

Multiply the decimal fraction 0.14 by 60 to reduce it to minutes.

Deflection angles may also be computed by using the tables of radii and deflection angles found in most handbooks. Although these tables are based upon the arc lengths rather than the chord lengths, they may be used nevertheless, because in this particular problem, there is no appreciable difference between a 25-foot chord and a 25-foot arc for a 10° curve. According to the tables, the deflection per foot of arc for a 10° curve is 3.0 minutes. Multiplying 22.78 by 3′ will give you 68.34 minutes or a deflection angle of 1° 8′.

Before you can calculate the rest of the deflection angles, you must make the appropriate correction for the use of 25-foot subchords. When an arc subtended by a

chord of 100 feet is subdivided into four equal parts, each of the four parts must be slightly longer than 25 feet. Figure 9–21 gives you the distance which you must add to each subchord for a particular degree of curve.

For a 10° curve and for subchords of 25 feet each, the correction factor is 0.03 feet. The corrected subchord is therefore 25.03 feet. Substituting in the deflection angle formula, you get

$$\begin{aligned} \text{deflection angle} &= \tfrac{1}{2}\,(10)\,\frac{(25.03)}{100} \\ &= \tfrac{1}{2}\,(2.503) \\ &= 1.2515. \end{aligned}$$

Converting the decimal fraction to minutes, you find the deflection angle is 1° 15′ to the nearest 30″.

Now for each 25.03 subchord, the deflection angle from the *P. C.* will increase by 1° 15. When the first 25.03-foot chord is swung in, the deflection angle from *P. C.*

Degree of curve (degrees)	For subchord lengths add			
	10 feet	20 feet	25 feet	50 feet
3	0. 001	0. 002	0. 003	0. 004
4	. 002	. 004	. 005	. 008
5	. 003	. 006	. 007	. 012
6	. 005	. 009	. 011	. 017
7	. 006	. 012	. 015	. 023
8	. 008	. 016	. 019	. 030
10	. 013	. 024	. 030	. 048
12	. 018	. 035	. 043	. 069
14	. 025	. 048	. 058	. 093
16	. 032	. 063	. 076	. 122
18	. 041	. 079	. 097	. 155
20	. 050	. 098	. 119	. 191

Figure 9–21.—Corrections for subchord lengths (chord definition).

(station 16 + 27.20) will be 1° 8′ plus 1° 15′ or 2° 23′. The 25.03-foot chord from station 16 + 50 locates station 16 + 75. At station 16 + 75, the deflection angle will be 1° 8′ plus 1° 15′ or 2° 23′; at 17 + 00, it will be 2° 23′ plus 1° 15′ or 3° 38′; at 17 + 25, 4° 53′; at 17 + 50, 6° 8′; at 17 + 75, 7° 23′; at 18 + 00, 8° 38′; and at 18 + 25, 9° 53′. Note that the last subchord between station 18 + 25 and the computed *P. T.* (18 + 42.22) is 17.22 feet. Calculate the deflection angle for the odd chord length of 17.22 feet. Substituting in the formula, we get

$$\begin{aligned}\text{deflection angle} &= \tfrac{1}{2}\,(10)\,\frac{(17.22)}{100}\\ &= \tfrac{1}{2}\,(1.72)\\ &= .86.\end{aligned}$$

Convert the decimal fraction to 52′ by multiplying it by 60. Add the 52′ to 9° 53′ to get 10° 45′.

To check this answer, note that the deflection angle at *P. I.* (21° 30′) is equal to the central angle (Δ). The sum of all the deflection angles of the entire curve from the *P. C.* to the *P. T.* is equal to ½ the central angle. In this problem, it is 10° 45′, which agrees with the final instrument reading at the *P. T.*

COMPOUND CURVES AND REVERSED CURVES.—A compound curve consists of two or more simple curves of different degrees of curve following one another in the same general direction and having a common tangent at the point where they join. The point where the two curves run together is called a point of compound curve (*P. C. C.*). A reversed curve consists of two simple curves which turn in opposite directions. The point where the two curves join is called the point of reversed curve (*P. R. C.*).

The principles of computation used for simple curves apply to all horizontal curves. Compound and reversed curves merely continue on from the end of the preceding

curve. Like any simple curve, a compound or reversed curve finally ends in a *P. T.*

Vertical Curves

Parabolic vertical curves are used on railway, highway, and airport runway profiles when the rate or direction of a grade changes. A SAG CURVE is one where a descending grade, is followed by an ascending grade or a flatter descending grade, while a SUMMIT CURVE is one in which an ascending grade is followed by a descending grade or a flatter ascending grade. The elements of a vertical curve are shown in figure 9–22.

The point of the intersection of a tangent (grade line) and the beginning of a vertical curve is called the *bvc* or *P.V.C.* The point of the intersection of a tangent (grade line) and the end of a vertical curve is called the *evc* or *P.V.T.* These points are identified by the station number and the elevation. The grade lines are designated as g_1 and g_2. The point of intersection of the tangents or grade lines is called *V*. The g_1 and g_2 are expressed as percentages of rise to a horizontal distance. If the grade line at *P.V.C.* or at *P.V.T.* slopes uphill, the gradient is

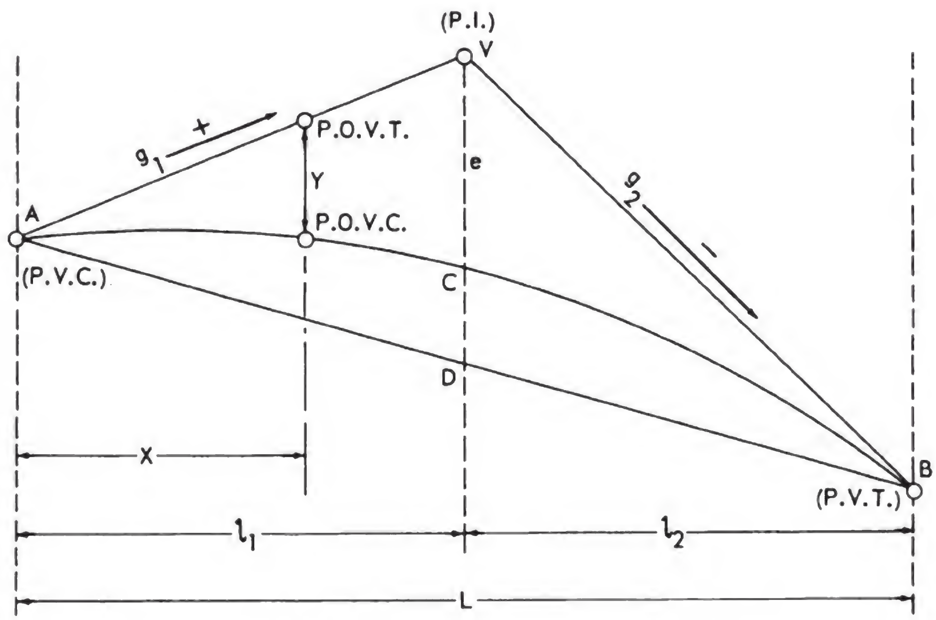


Figure 9–22.—Elements of a vertical curve.

marked +; if downhill, it is marked —. For example, a gradient of —0.5 percent or —½ percent, means a downhill slope or drop in elevation of one-half foot per 100 feet of horizontal distance. G is the algebraic difference of the grades. Thus, $G = g_1 - g_2$.

L is the length of the total curve measured as a horizontal distance from $P.V.C.$ to $P.V.T.$; l is the length of the curve measured as a horizontal distance in stations from the vertex V to the $P.V.C.$; l_2 is the length of the curve measured as a horizontal distance in stations from the vertex to the $P.V.T.$. Note that for a symmetrical vertical curve, $l_1 = l_2 = \frac{1}{2} L$ and is referred to as the half-length of the curve in stations. The e is the vertical distance (offset) from the vertex to the curve. In a symmetrical curves, e is the offset from the vertex to the middle of the curve. *P. O. V. C.* is any point on the vertical curve, and *P. O. V. T.* is any point on a vertical tangent. The horizontal distance in stations from the *P.V.C.* to any *P. O. V. C.* or *P. O. V T.* is x, and the vertical distance (offset) from any *P. O. V. T.* to its corresponding point on the *P. O. V. C.* is y. The following formula is helpful in solving for y:

$$y = \left(\frac{x}{l}\right)^2 e.$$

A symmetrical vertical curve is one in which the horizontal distance from the V to the *P.V.C.* is equal to the horizontal distance from the V to the *P.V.T.*, or l_1 equals l_2. For a discussion of unsymmetrical vertical curves, see *Surveyor 1 & C*, NavPers 10633–A.

Suppose that you are given the following data for a symmetrical vertical curve:

$g_1 = +9\%$
$g_2 = -7\%$
L = 400.00′, or 4 stations.
V. is station 30 + 00.
Elevation of V = 239.12 feet.

The problem is to compute the grade elevation of the curve, to the nearest hundredth of a foot, at each 50-foot station. Figure 9–23 shows the vertical curve to be solved.

First, prepare a worksheet like that shown in figure 9–24. Column 1 lists the stations. Now, knowing the gradients of the tangents and the elevation and station at *V*, you can compute the elevations and set the stations on *P.V.C.* and *P.V.T.* The gradient (g_1) of the tangent at *P.V.C.* is given as + 9 percent. This means a rise in

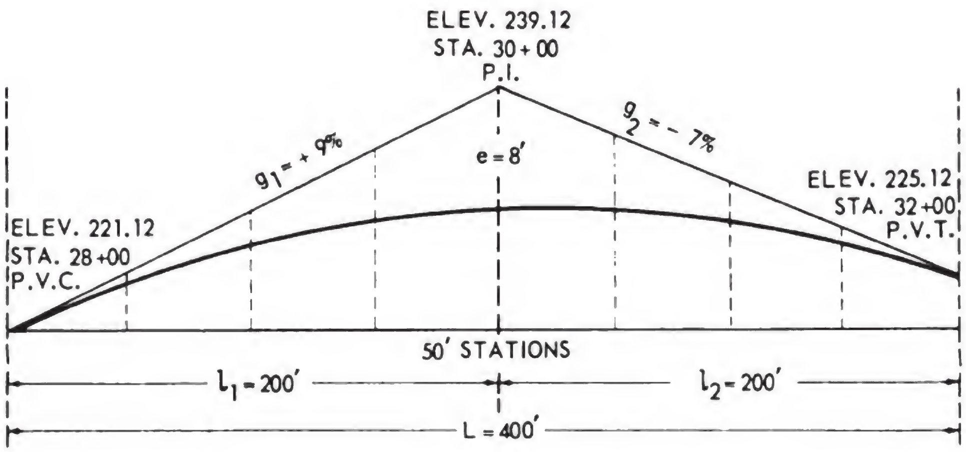


Figure 9–23.—Symmetrical vertical curve problems.

elevation of 9 feet for every 100 feet of horizontal distance. Since *L* is 400.00 feet and since this is a symmetrical curve, l_1 equals l_2 equals 200.00 feet. Therefore, there will be a difference of 9 × 2 or 18 feet between the elevation at *V* and the elevation at *P.V.C.* The elevation at *V* in this problem is given as 239.12 feet. The elevation at *P.V.C.*, therefore, is 239.12 minus 18 or 221.12 feet.

Calculate the elevation at P.V.T. in a similar manner. The gradient (g_2) of the tangent at *P.V.T.* is given as — 7 percent. This means a drop in elevation of 7 feet for every 100 feet of horizontal distance. Since l_1 equals l_2 equals 200 feet, there will be a difference of 7 × 2 or 14 feet between the elevation at *V* and the elevation at

Stations	Elevations on tangent	x/l	$(x/l)^2$	Vertical offsets	Grade elevation on curve	First difference	Second difference
28+00 (*PVC*)	221. 12	0	0	0	221. 12		
						+4. 00	
+50	225. 62	1/4	1/16	0. 50	225. 12		+1. 00
						+3. 00	
29+00	230. 12	1/2	1/4	2. 00	228. 12		+1. 00
						+2. 00	
+50	234. 62	3/4	9/16	4. 50	230. 12		+1. 00
						+1. 00	
30+00 (*P. V. L*)	239. 12	1	1	8. 00	231. 12		+1. 00
						. 00	
+50	235. 62	3/4	9/16	4. 50	231. 12		+1. 00
						−1. 00	
31+00	232. 12	1/2	1/4	2. 00	230. 12		+1. 00
						−2. 00	
+50	228. 62	1/4	1/16	. 50	228. 12		+1. 00
						−3. 00	
32+00 (*PVT*)	225. 12	0	0	0	225. 12		

Figure 9–24.—Computation of elevations on a symmetrical vertical curve.

P.V.T. The elevation at *P.V.T.*, therefore, is 239.12 feet minus 14 feet or 225.12 feet.

In setting stations on a vertical curve, remember that the length of the curve (L) is always measured as a horizontal distance. The half-length of the curve is the horizontal distance from V to *P.V.C.* In this problem, l_1 equals 2 + 00 feet. This is equivalent to two 100-foot stations and may be expressed as 2 + 00. Thus, if the station at V is given as 30 + 00, the station at *P.V.C.* is 30 + 00 minus 2 + 00 or 28 + 00. The station at *P.V.T.* is 30 + 00 plus 2 + 00 or 32 + 00. Refer to column 1 in figure 9–24.

Now, since there is a 9-foot rise in elevation for every 100 feet of horizontal distance from *P.V.C.* to V, for every 50 feet of horizontal distance there will be a rise of 4.50 feet in elevation. The elevation on the tangent at station 28 + 50 is 221.12 plus 4.50 or 225.62 feet. The elevation on the tangent at station 29 + 00 is 225.62 plus 4.50 or 230.12 feet. The elevation on the tangent at station 29 + 50 is 230.12 plus 4.50 or 234.62 feet. The elevation on the tangent at station 30 + 00 is 234.62 plus 4.50 or 239.12 feet.

To find the elevation on the tangent at any 50-foot station starting at *P.V.C.*, add 4.50 to the elevation at the preceding station until you reach the V. At this point, use a slightly different procedure in calculating elevations because the curve slopes downward toward the *P.V.T.* Think of the elevations as being divided into two groups —one group running from the *P.V.C.* to the V, the other group running from V to the *P.V.T.*

Proceeding downhill on a gradient of — 7 percent from V to *P.V.T.*, there will be a drop of 3.50 feet for every 50 feet of horizontal distance. To find the elevations at stations between V and the *P.V.T.* in this particular problem, subtract 3.50 from the elevation at the preceding station. The elevation on the tangent at station 30 + 50 is 239.12 minus 3.50 or 235.62 feet. The elevation on the tangent at station 31 + 00 is 235.62 minus 3.50 or 232.12 feet. The elevation on the tangent at

station 31 + 50 is 232.12 minus 3.50 or 228.62 feet. The elevation on the tangent at station 32 + 00 (*P.V.T.*) is 228.62 minus 3.50 or 225.12 feet. The last subtraction provides a check on your work thus far. The computed elevations are listed in column 2 in figure 9–24.

Next calculate e, the middle vertical offset at V. This is calculated by using the formula $e = \frac{LG}{8}$, where L is the length of the curve measured in horizontal stations and G is the algebraic difference in gradients. First find G, using the formula.

$$\begin{aligned} G &= g_1 - g_2 \\ &= +9 - (-7) \\ &= +16. \end{aligned}$$

Therefore

$$\begin{aligned} e &= \frac{LG}{8} \\ &= \frac{4 \times 16}{8} \\ &= 8.00 \text{ feet.} \end{aligned}$$

Compute the vertical offsets at each 50-foot station, using the formula $y = \left(\frac{x}{l}\right)^2 e$. To find the vertical offset at any point on a vertical curve, first find the ratio $\frac{x}{l}$, then square it and multiply by e. For example, at station 28 + 00, the ratio of $\frac{x}{l} = \frac{50}{200} = \frac{1}{4}$. Therefore, $\left(\frac{x}{l}\right)^2 = \frac{1}{16}$. The vertical offset at station 28 + 50 equals $\frac{1}{16} \times 8$ or 0.50. Repeat this procedure to find the vertical offset at each of the 50-foot stations. The results are listed under columns 3, 4, and 5 in figure 9–24.

Now compute the grade elevation at each of the 50-foot

stations. When the curve is on a crest, subtract the vertical offset (the figure in column 5) from the elevation on the tangent (the figure in column 2). For example, the grade elevation at station 28 + 50 is 225.62 minus 0.50 or 225.12 feet. Obtain the grade elevation at each of the stations in a similar manner. Enter the results under column 6 in figure 9–24. Note that when the curve is in a dip, you would ADD the vertical offset to the elevation on the tangent.

Finally, check your work. Do this by finding the second differences shown in column 7 of figure 9–24, because one of the characteristics of a symmetrical parabolic curve is that the second differences between successive grade elevations at full stations are constant. When you round off your grade elevation figures according to the degree of precision required, you introduce an error which will cause the second differences to vary slightly from one another. However, the slight variation does not detract from the value of the second differences as a check on your computations. You are cautioned that the second differences will not always come out exactly even and equal. It is merely a coincidence that the second differences have come out exactly the same in this particular problem.

Note that in computing the differences, you must take into consideration the plus or minus signs. For example, the grade elevation at station 28 + 00 is 221.12 feet and the grade elevation at station 28 + 50 is 225.12. That is, there is a + 4.00 difference between stations 28 + 50 and station 28 + 00. If the elevation at 28 + 00 had been 225.12 and that at station 28 + 50 had been 221.12, there would have been a − 4.00 first difference. Similarly there is a second difference of a + 1.00 between the first difference of + 4.00 and + 3.00. Had these figures been reversed, the second difference would have been a − 1.00.

AERIAL PHOTOGRAPHS

Aerial photographs are very useful to the military services, especially in time of war. They are far more

detailed than maps, and they can be made much more quickly and easily. They can also be made of areas which are inaccessible, such as areas which are held by enemy forces. They have certain disadvantages: they are not easy to read and there is always some distortion and displacement in an aerial photograph. In combination with a map of an area, however, aerial photographs are invaluable. On the photograph, relief is not very clear, but relief, a slowly changing thing, will be shown on a good map. The photograph on the other hand, will show the changing cultural features such as the road net.

There are several types of vertical photographic coverage. A series of consecutive vertical photographs, usually overlapping by 60 percent, but not necessarily overlapping, is called a SINGLE VERTICAL RECONNAISSANCE STRIP. (See fig. 9–25.) This type of coverage is used on beaches, roads, railroads, or other long, narrow targets.

When the area to be photographed is of such width that it cannot be covered at the desired scale by means of a single vertical strip, then a system of parallel strips is employed. (See fig. 9–26.) The overlap between photographs in each strip (side overlap) varies from 10 to 50 percent. When the target is heavily defended, this type of coverage is usually accomplished simultaneously by several aircraft (one for each strip desired). Over weakly defended areas, a single aircraft, flying successive flights, may accomplish the same result. Multiple-strip photography is of the following types, listed in order of increasingly exacting requirements: (a) reconnaissance coverage, (b) combat mapping, and (c) precise mapping.

OBLIQUE PHOTOGRAPHS are those taken with the axis of the camera intentionally tilted from the vertical. There are two main types of oblique photographs:

1. Low oblique, shown in figure 9–27. An oblique photograph which does not include the horizon.

2. High oblique, shown in figure 9–27. An oblique which includes the horizon.

Oblique photography is taken in various ways:

1. As individual exposures covering the target from predetermined angles and altitudes, or as operational conditions permit.

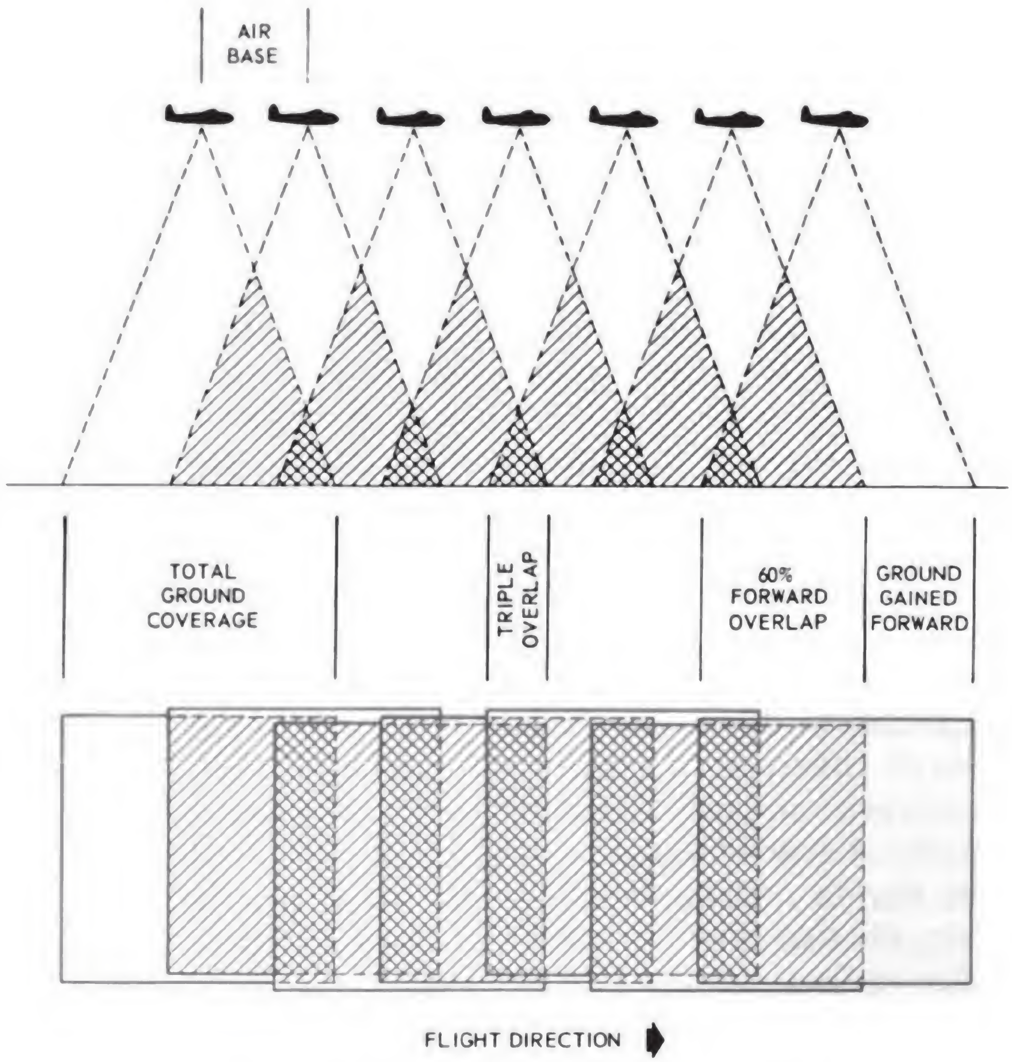


Figure 9–25.—Single vertical reconnaissance strip photography.

2. As stereoscopic pairs or triplets covering the target according to a predetermined plan, or as operational conditions permit.

3. As oblique strips. Consecutive oblique photographs which need not overlap but usually overlap 60 percent

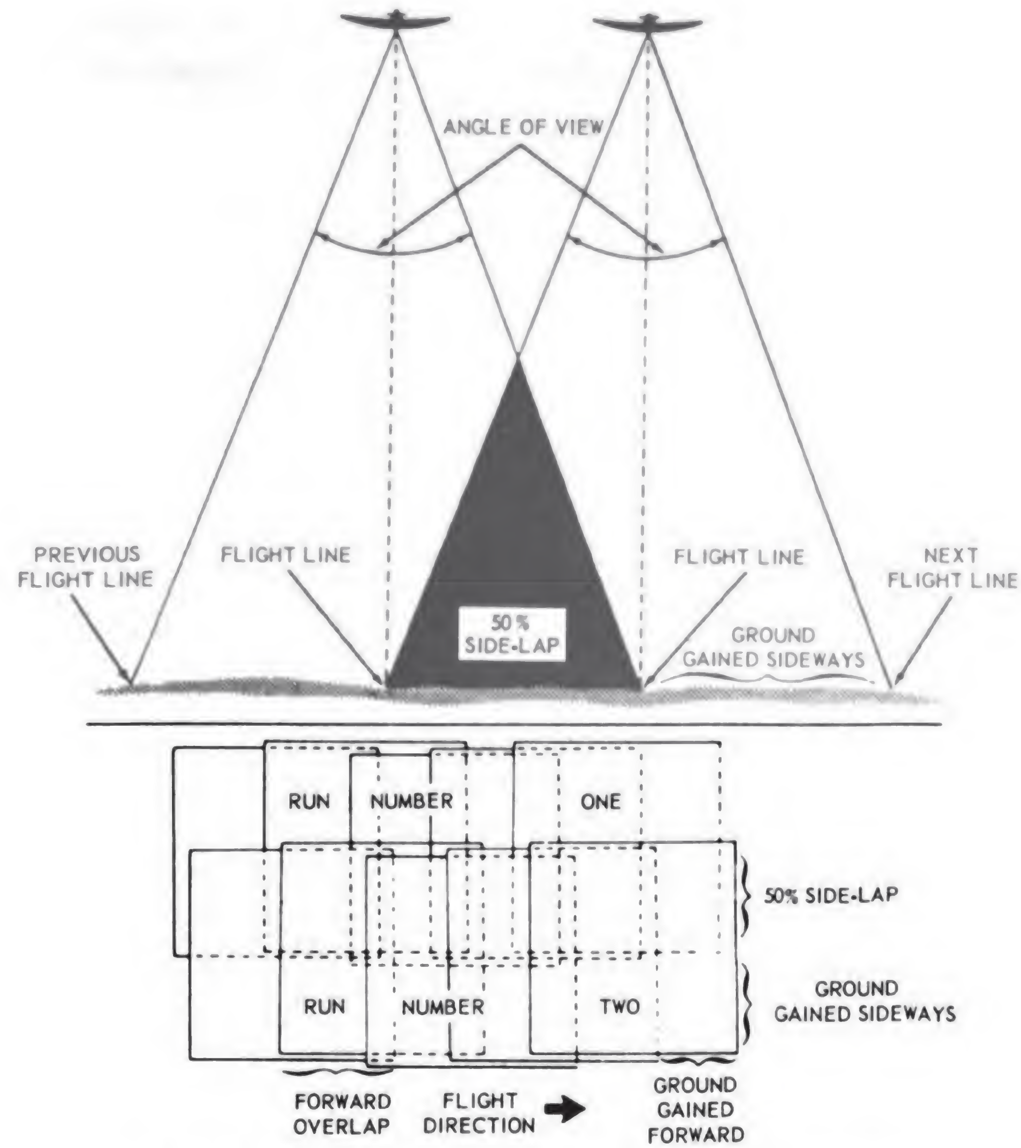


Figure 9–26.—Multiple vertical reconnaissance strip photography.

at the primary target (mean beach line, central portion of the target, etc.). Complete oblique stereoscopic coverage of the target is provided by this method.

DICING RUNS are vertical or oblique runs made at high speed and low altitude in order to cover small, heavily defended areas. Dicing is usually accomplished by fighter aircraft.

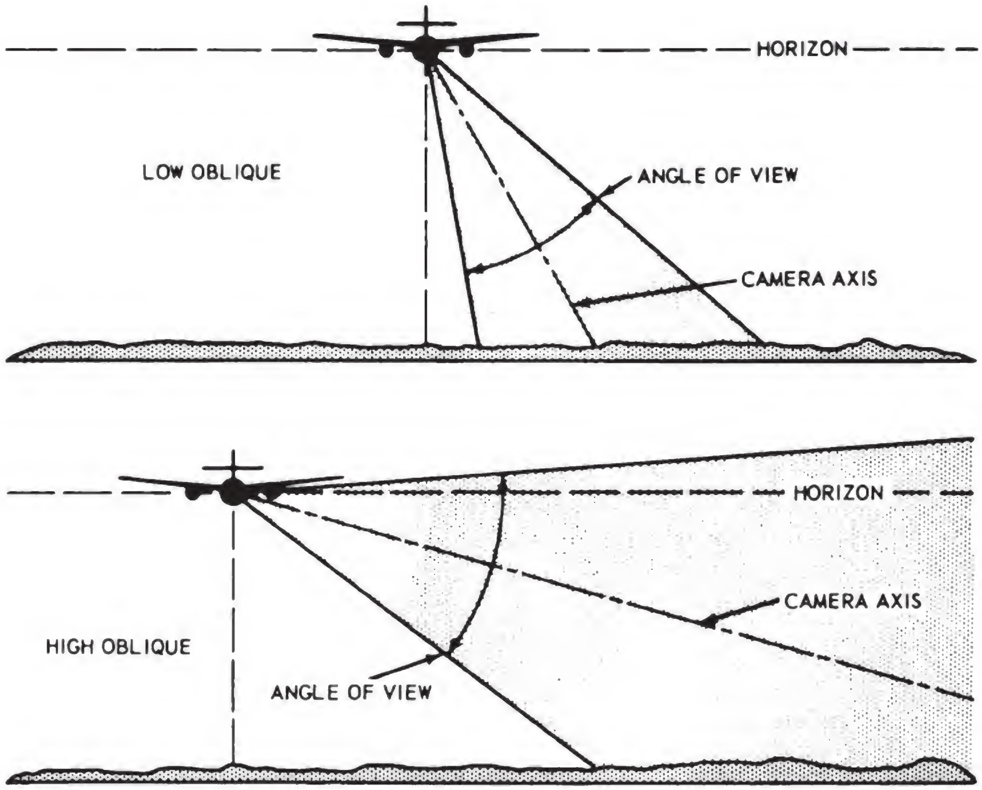


Figure 9–27.—Types of aerial oblique photographs. The small difference between the true and apparent horizons has not been considered in these diagrams.

The TRIMETROGEN installation consists of three wide-angle cameras (one vertical and a left and a right oblique) whose fields overlap each other so that a photographic strip is made from horizon to horizon across the flight line. The trimetrogon installation is used for the following purposes:

1. Reconnaissance flights. Used chiefly to expedite plotting and to make target searches; often used to supplement long-focal-length cameras in large aircraft.

2. Control trimetrogon photography. Used as a supplement to precise basic vertical mapping photography.

3. Trimetrogon charting photography. Used for small-scale aeronautical charting.

Aerial Photographic Titling

A standardized system for titling aerial photography is being evolved by the Armed Forces of the United States. Until this is accomplished, each service will use its own system.

The current Navy system creates a complete title with 13 separate categories of information. Except when hand-titled, the title on each photograph must include all 13 categories. When hand-titled, all negatives will be captioned with items 1 through 7 and the first and last photograph of each roll or run will be completely titled.

Titling data is placed in a single line in the following sequence:

100 USN VC–61 (CV–45) 256/2 10 Nov. 51 12″
20,000′ V 75° 30′ W R 1300 BAH CONFIDENTIAL
25° 30′ N

A listing of the data follows:

Item No.	*Example*	*Description*
1	100	Negative (or Exposure) number
2	USN	Service (USN, USAF, USA, etc.)
3	VC–61 (CV–45)	Squadron and detachment
4	256/2	Sortie and run number
5	10 Nov. 51	Date
6	12″	Focal length of lens of camera
7	20,000′	True altitude recorded in feet above sea level
8	V	Camera position and angle: V = vertical, VR = vertical right, VL = vertical left, OR = right oblique, OL = left obilque, ON = nose oblique, OT = tail oblique installation, RT = right oblique, LT = left oblique, VT = vertical for trimetrogon installation.

Item No.	*Example*	*Description*
9	75° 30'W 25° 30'N	Geographic coordinates
10	R	Kind of photography: R = infrared, N = night, M = mirror, NR = night infrared, CD= camouflage detection.
11	1300	Greenwich Civil Time
12	BAH	Descriptive title (designating area symbol not to exceed three letters)
13	RESTRICTED	Classification

Scale Determination

Linear scale is the relationship between distances on a map or photo and the actual ground distance. Scale is normally expressed in one of three ways: as a representative fraction (R. F.) in which the numerator is unity, such as 1/10,000: as a ratio, such as 1:10,000; or as a relationship between dissimilar units, such as "1 inch equals 1 mile." In the case of the representative fraction or ratio, the numerical relationship is valid regardless of the unit of measure used. That is, 1 inch on the map equals 10,000 inches on the ground or 1 meter on the map equals 10,000 meters on the ground. A scale expressed in dissimilar units which must be converted to fractions for most computations has the advantage of being better understood by the user. A person familiar with English units of measure easily estimates an inch on the map and knows that it represents 1 mile on the ground. The representative fraction for this scale is 1/63, 360; that is, 1 inch on the map equals 63,360 inches on the ground (which is the number of inches in a mile). A person familiar only with metric measure would have little use for the "1 inch equals 1 mile" relationship but he would understand the ratio or the R. F.

Basically there are four methods of obtaining the scale of a photograph. Generally speaking, in decreasing order

of accuracy, they are the determination of the relationships of: (1) photo to ground, (2) photo to map, (3) photo to object of known dimension, and (4) focal length of camera to altitude of camera.

When the distance between two points on the photo which can be located on the ground or on a map is measured, the horizontal measurements of these distances on the photo and on the ground or map form a ratio. This ratio is the same as that between the R. F.'s of the photo and of the map. Thus:

Map measurement $= 0.108$ foot
Photo measurement $= 0.432$ foot
R. F. of the map $= 1/50{,}000$
R. F. of the photo $= 1/X$

$$\frac{0.108}{0.432} = \frac{X}{50{,}000}$$

$$0.432X = 5{,}400$$

$$X = 12{,}500$$

A normally satisfactory scale determination can be made by relating the measurement of an object on the photo to the actual known dimensions of the object. Such objects might be aircraft, ships, port facilities, railroads, or buildings. Thus:

The actual wing span of a DC–3 aircraft is 96 feet. The measurement on a photo is 0.016 feet.

$$\text{R. F.} = \frac{\text{measured image length}}{\text{actual length}}$$

$$= \frac{0.016}{96}$$

$$= 1/6{,}000.$$

Properly titled aerial photography will include, among other things, the focal length of the camera and the alti-

tude above sea level from which the photo was taken. Inserting this information, expressed in the same unit, $\frac{H \text{ (height of aircraft)}}{f \text{ (focal length of camera)}}$ will give the R. F. of the photo. Thus:

The focal length is 36 inches.
The height of the aircraft is 18,000 feet.

$$\text{R. F.} = \frac{36 \text{ inches}}{18{,}000 \text{ feet}} = \frac{3 \text{ feet}}{18{,}000 \text{ feet}}$$
$$= 1/6{,}000.$$

Another formula which is generally used is $\frac{12 \text{ (a basic unit)}}{\text{focal length of camera}} \times$ height of plane. Thus, $\frac{12}{36} \times 18{,}000 = \frac{18{,}000}{3} = 6{,}000$. This scale is then written 1/6,000.

In areas which have altitudes other than sea level, the altitude figure found in the photo title is subject to correction because of the nature of the instrument recording the height. The altimeter reports barometric pressure translated into feet above sea level. It will indicate approximately the same pressure for 18,000 feet whether the aircraft is flying over Death Valley or the Rockies. But, obviously, the scales of pictures taken of these areas from an indicated 18,000 feet will not be the same. When the ground elevation is known, the f/H formula is refined to $f/(H\text{-}h)$; in which h is the elevation, in feet above sea level, of the area being photographed. This will result in a more accurate scale.

The four methods of determining scale have several error factors in common which must be given consideration. These factors are:

1. Limits of resolution of the photo.
2. Film, prints, and map stretching and shrinking.
3. Lens distortion.
4. Variations in elevation of terrain.

In addition, the photo-distance/map-distance method requires very accurate measurements on small-scale maps or the availability of large-scale maps which will afford the probability of accurate measurements.

The photo-distance/object-of-known-dimension method is also plagued with its own peculiar problem. Because the largest part of photo-measurement error is independent of the total length of measurement, the percentage of error increases as the distance measured decreases. Therefore, when the objects of known length are very small, the percentage of error is likely to be high.

The focal-length/height-of-aircraft approach requires the determination of the effective altitude at which the photo was taken, giving due consideration to altimeter errors and the altitude above sea level of the area being photographed.

In any consideration of scale, it is important to assess the accuracy of the map being used. A very small-scale map, for example, will often seem to deny measurements made on the photo. The purpose for which the map was constructed is often a key to its accuracy. The age of the map, the organization which made the map, and other border information are among the factors which must be considered in the evaluation.

Measurements used to determine scale should, if possible, cover the entire photograph. Discrepancies not easily picked up by observation, such as tilt, may be brought to light by extending the area of measurement to all parts of the photo. Special care should be applied in measuring photos taken with short-focal-length cameras in areas of varying elevation, because of the likelihood that such photography will contain a wide range of scales.

Mosaics and Overlays

The aerial photographic mosaic is constructed from two or more overlapping prints joined so that they form

a single picture. Usually, vertical photographs are used and a maplike result is obtained; however, oblique photographs may be used, in which case the result is a panorama. The aerial photographic masaic, often called simply MOSAIC, has become increasingly useful in cartography and related fields since World War I. Large geographic areas may be represented in this manner, with each feature of terrain assuming its natural appearance and approximating its proportionate size.

In a controlled mosaic, the photographs are placed by fitting them to a control plot which has been adjusted to ground control. The accuracy of the mosaic as a map is in proportion to the quality of the photographs, the degree of care used in its preparation, and the density of the ground control.

Uncontrolled mosaics are more simple to prepare and are quite satisfactory for many purposes. While precise measurements cannot be made, the short distances often required in intelligence reports can be adequately approximated. Uncontrolled mosaics are excellent for illus-

Figure 9–28.—Aerial photograph.

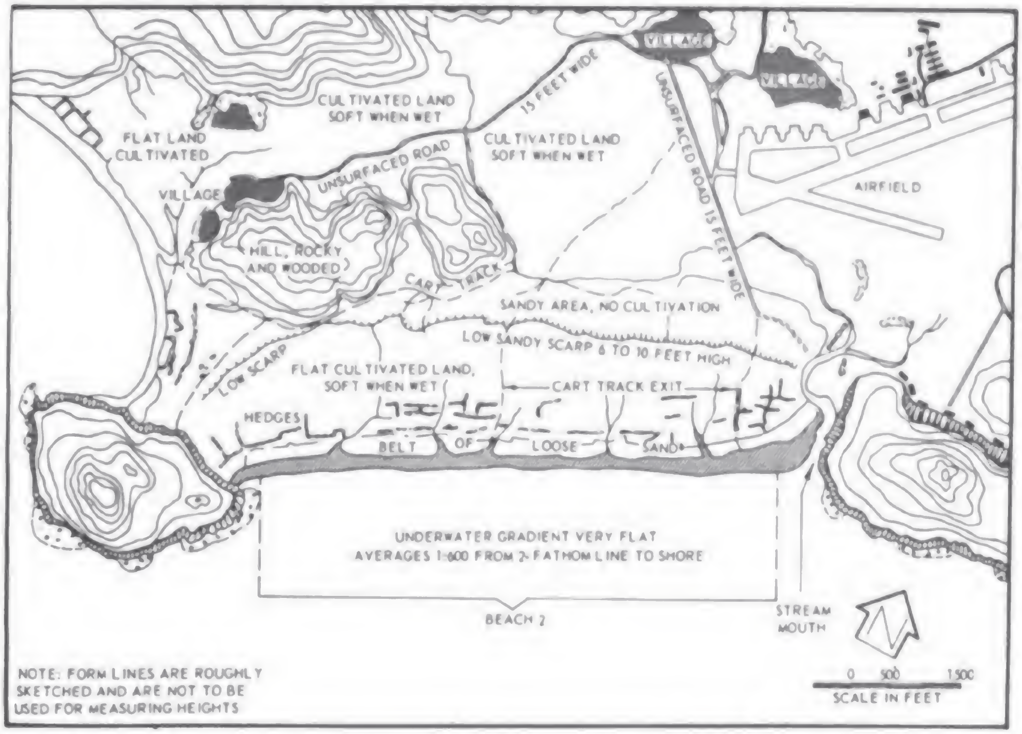


Figure 9–29.—Tracing made from aerial photograph on facing page.

trating reports or briefings. A procedure for assembling uncontrolled mosaics is given in the *Photographic Interpretation Handbook,* NavAer 10–35–610.

Aerial photographs may be converted into line maps by the use of overlays. Usually, these are made by tracing the details from the photograph on transparent paper or vellum and adding such marginal data as desired. This may then be reproduced quickly by contact printing or lithography. Figure 9–28 shows a vertical aerial photograph and figure 9–29 shows the overlay made from it.

QUIZ

1. How is the precision of measurement standard for a survey usually expressed?
2. Define a CLOSED TRAVERSE
3. In what terms are the lengths of the courses of a traverse stated.
4. What is an azimuth angle?
5. (a) How is a deflection angle measured? (b) A right deflection angle? (c) A left deflection angle?
6. What is the formula for the sum of the degrees of the interior angles in a polygon?
7. What should the algebraic sum of all the deflection angles for a course equal?
8. (a) How are bearings measured? (b) How is the quadrant in which the bearing falls defined?
9. If the course at station 1–2 has a right deflection angle of 120°03′ and the preceding course has a bearing of N65°51′W, what is the bearing at station 1–2?
10. In order to find the bearing of a course from an observed interior angle and the bearing of the previous course, how should the angle be measured?
11. (a) What are horizontal control points? (b) Why is it important that they be carefully located?
12. (a) What is the latitude of a line? (b) What is the departure of a line?
13. Give the equation for computing latitude and departure?
14. What is the sign for: (a) A latitude for a course with a northerly bearing. (b) A latitude for a course with a southerly bearing. (c) A departure for a course with an easterly bearing. (d) A departure for a course with a westerly bearing.
15. What is the ERROR OF CLOSURE of a traverse?
16. How do you find the precision of measurement for a survey of a closed traverse?
17. What is the compass rule for making corrections to latitudes and departures to balance a traverse?
18. Give the formula for the average-end-area method of determining the volume between cross sections or end areas.

19. Describe two different ways of defining the degree of curve of a horizontal curve.

20. Why is it important to know which definition for the degree of curve is being used before you select tables of computed quantities for a horizontal curve?

21. What type of curve is used for vertical curves on railways, highways, and airport runway profiles when the rate or direction of a grade changes?

22. What are two types of vertical aerial photographic coverage?

23. Describe the two types of oblique aerial photographs.

24. Describe the installation for taking trimetrogon photographs.

25. List the four methods of determining the scale of a photograph in decreasing order of their accuracy.

CHAPTER 10

HYDROGRAPHIC DRAFTING

INTRODUCTION

As a topographic draftsman, you may also be assigned to a survey ship or to a construction battalion engaged in waterfront construction. The U. S. Navy Hydrographic Office is responsible for the hydrographic work in foreign areas, and survey ships are equipped to make surveys of coastlines and to do oceanographic work. Draftsmen may be assigned to assist in plotting field surveys on these ships. Hydrographic surveys are also carried out for the purpose of obtaining data required for waterfront construction, measuring the capacities of lakes and reservoirs, and determining the capacities and depths for dredging operations.

Many of the operations of hydrographic surveying are essentially the same as those for topographic surveying. The main difference is that points must be located on a water surface, sometimes at a great distance from shore, and the depth of the water at these points must be determined. Both hydrographic and topographic surveying require the establishment of horizontal and vertical control. The principles of horizontal and vertical control surveys, involving triangulation, traverses, trigonometric, barometric, or differential leveling are also applicable to hydrographic surveys.

SURVEYING INSTRUMENTS AND PROCEDURES

Instruments used in hydrographic surveying include TRANSITS, THEODOLITES, which are transits that give very accurate readings, and SEXTANTS. The sextant is a portable instrument used to measure the angle between two objects up to 120 degrees. Unlike the transit, it does not require a stable support and is therefore especially suitable for measuring angles from a boat or ship. The angles are read from a scale engraved on an arc at the base of the instrument. The sextant gets its name from the fact that this arc is about one-sixth of a circle.

A LEAD-LINE or a SOUNDING POLE is adequate for taking soundings under certain conditions. However, they have been largely replaced by the echo sounder. The FATHOMETER is one type of echo sounder. This type of instrument measures the depth of water by determining the time required for sound waves to travel at a known velocity, from a point on a ship near the surface of the water to the sea bottom and return. The machine converts the time interval to a measurement in feet or fathoms and indicates this measurement on a visual depth indicator or records it graphically on a rotating drum. The graphic record is called a FATHOGRAM.

Soundings are usually located at regular intervals, such as one sounding every 5 minutes. The proper length of time to be allowed between two successive soundings is determined by the depth of the water, the method of observation, and the distance between adjacent soundings. Various methods are available by which soundings are located.

Figure 10–1 shows two sets of intersecting ranges laid out for sounding locations. The ranges in each set are parallel. The targets are laid out and arranged according to the area to be sounded. Where small areas exist along and out from a shore line, about 10-foot intervals between soundings may possibly be allowed. However, if the area concerned is extremely large, and if only a

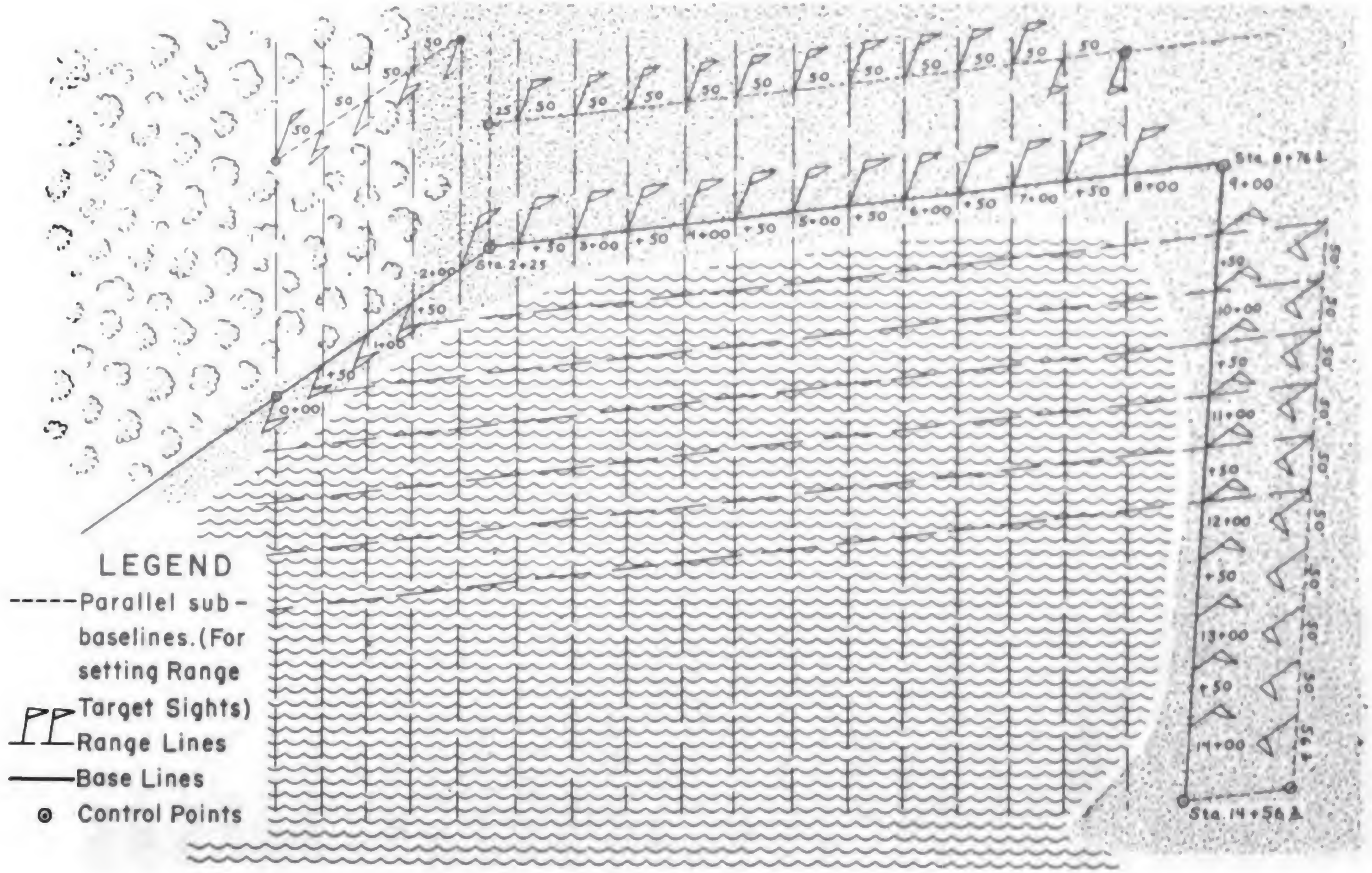


Figure 10–1.—Alignment of cross ranges.

general relief of the bottom is desired, intervals of about 50 feet or even more are satisfactory. Soundings will be taken at all range intersections. When shore conditions permit, one set of parallel ranges and one set of ranges radiating from a single point may be used, as shown in figure 10–2.

TRIANGULATION FROM SHORE, also known as the TWO ANGLES FROM SHORE METHOD, requires the use of two transits—one at each end of a known baseline on shore. Ranges may or may not be used. The two transitmen simultaneously read the angle from the baseline to the boat location. A third transit may be used as an additional check.

Each transitman sets the horizontal circle at 0°, sights at the other transit, and clamps the lower motion of the instrument. The upper clamp is loosened, and the tele-

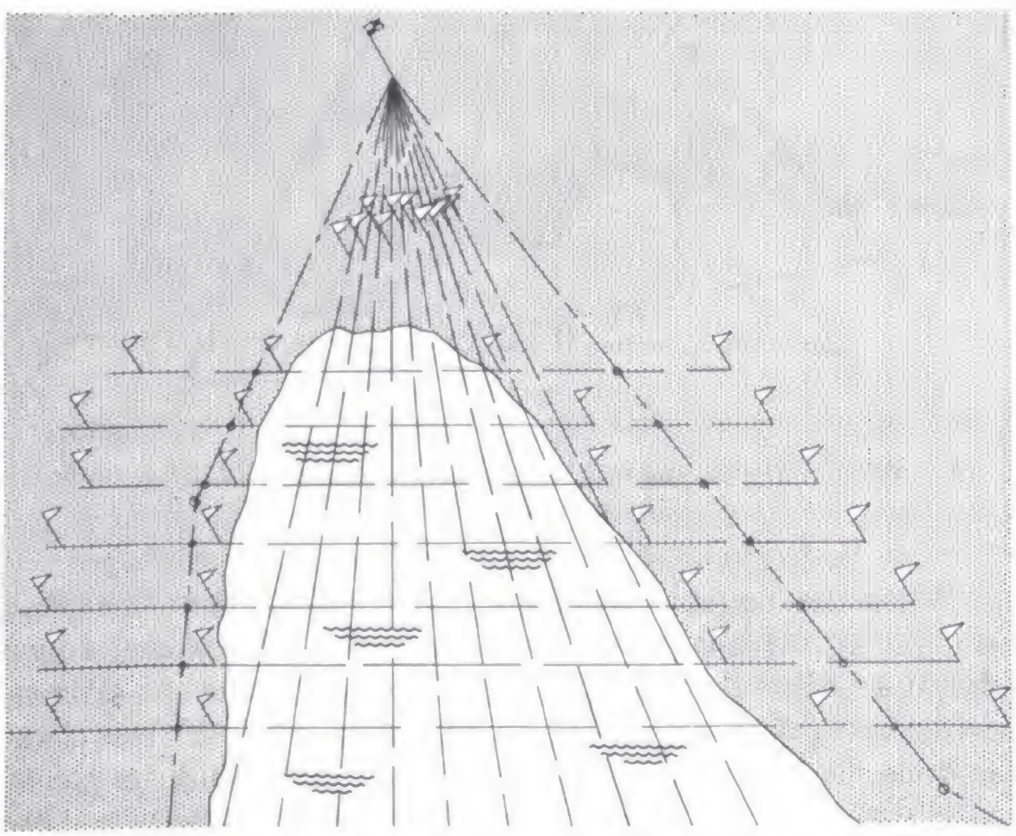


Figure 10–2.—Radial and parallel ranges.

scope is pointed at the boat from which the soundings are being taken. Now, as the boat is rowed along its course, the sounding rod, or line, is followed by the instrumentmen. A signal is given from the boat (usually with a white or colored flag), and each transitman immediately perfects his sighting on the bow of the sounding boat and clamps the upper plate. At this instant, the leadsman, standing in the bow, takes the sounding. The two angles, one from each end of the baseline, accurately locate the boat's bow. This position is usually plotted by triangulation from the baseline. The way this method works is shown in figure 10–3. Notice that an angle is measured simultaneously at *A* and at *B*, to the boat at *C*.

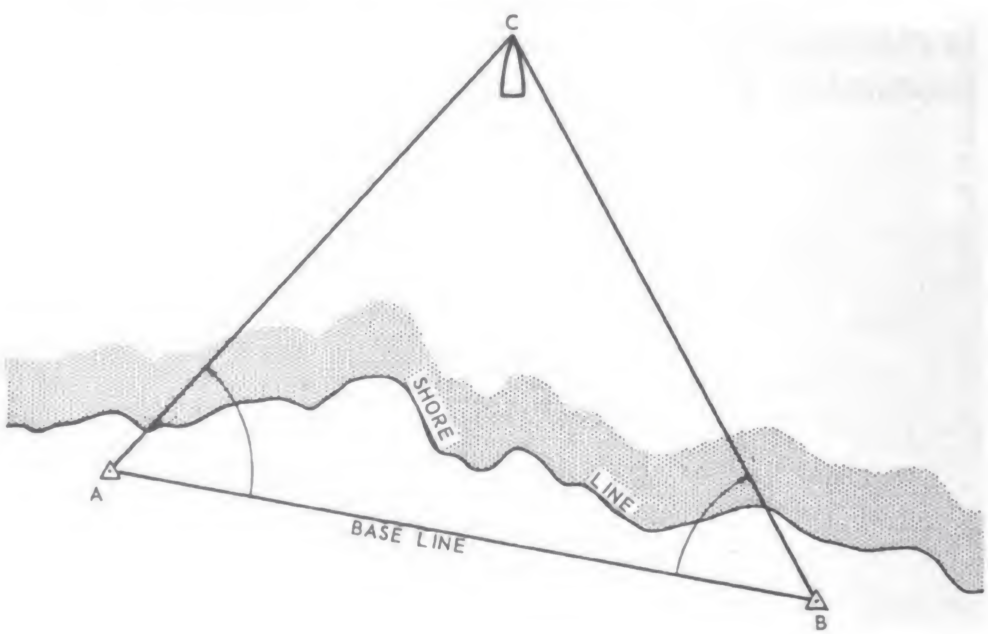


Figure 10–3.—Triangulation method.

When no ranges are used, it is important that the boat be steered on a definite compass course or toward some definite object on the far shore to prevent the soundings from being taken in a hit and miss fashion. Unless this is done, the soundings may be spaced too closely in parts of the area while other sections may be inadequately covered. Soundings, therefore, are often located by a com-

bination of ranges and one or two transits. Figure 10–4 shows soundings located by using one set of ranges and one transit on shore. This is known as the TRANSIT AND RANGES FROM SHORE METHOD. As the boat is rowed out over one range and back over another, the transitman reads the angle to the boat location whenever he receives the signal.

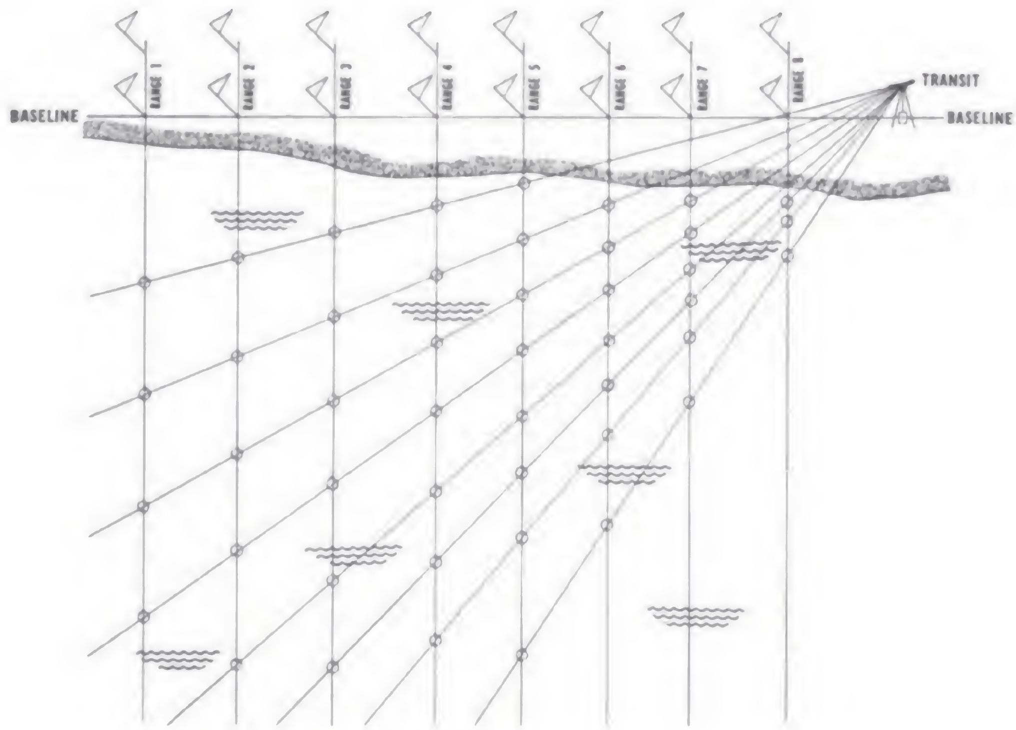


Figure 10–4.—Soundings by transit and range alignment.

Location of soundings by TRIANGULATION FROM THE BOAT requires the use of one or two sextants. Three control points must be visible on the shore from each sounding location. The line from the boat to the central control point is taken as the sextant baseline as indicated in figure 10–5. If two sextants are available, the instrumentmen simultaneously read the angles from the sextant baseline. One man reads the angle to the left; the other reads the angle to the right.

For identification purposes and for reference, all control stations used in connection with subaqueous surveys

are usually assigned names, as shown in figure 10–5. The following rules are used in selecting names of control stations: names of five or more letters are usually assigned to triangulation or traverse stations; those of four letters are used to designate marked topographic stations, shoran stations, electronic position indicator stations, and temporary topographic and hydrographic stations used by ships; buoys and temporary topographic and hydrographic stations used in smallboat surveys are generally designated by three-letter names, as shown in figure 10–5. To avoid possible duplication, a written record should be kept of the list of names as they are assigned.

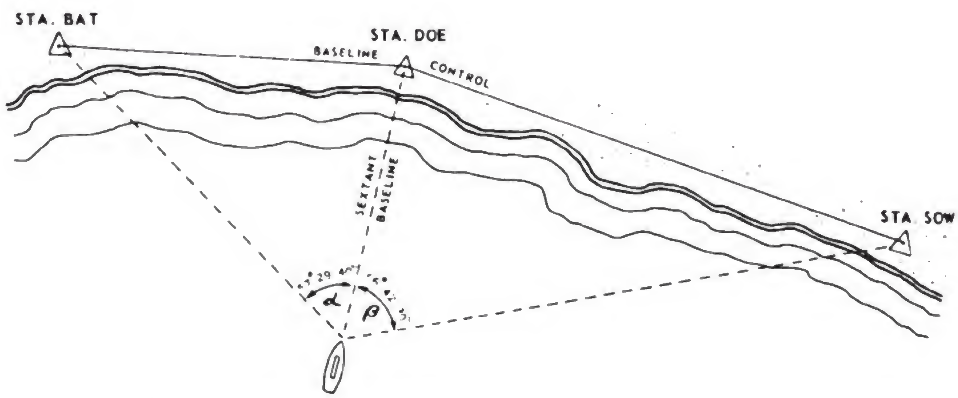


Figure 10–5.—Two-sextant method for locating a sounding from a boat.

Knowing angle α and angle β and using a three-arm protractor, you can find the location of the boat at the exact time the sounding was made and the angles were measured. This procedure is an application of the three-point problem used in plane surveying.

The accuracy or strength of the fix depends upon the relative positions of the signals. The fix is strong if the three stations are nearly in line or if the middle station is closer to the boat than the other two. The fix is weak if the boat is on the circle passing through the three stations. Such weak fixes are called swingers, as shown in figure 10–6, because the location of the boat can be in an indeterminate number of positions. Great care and

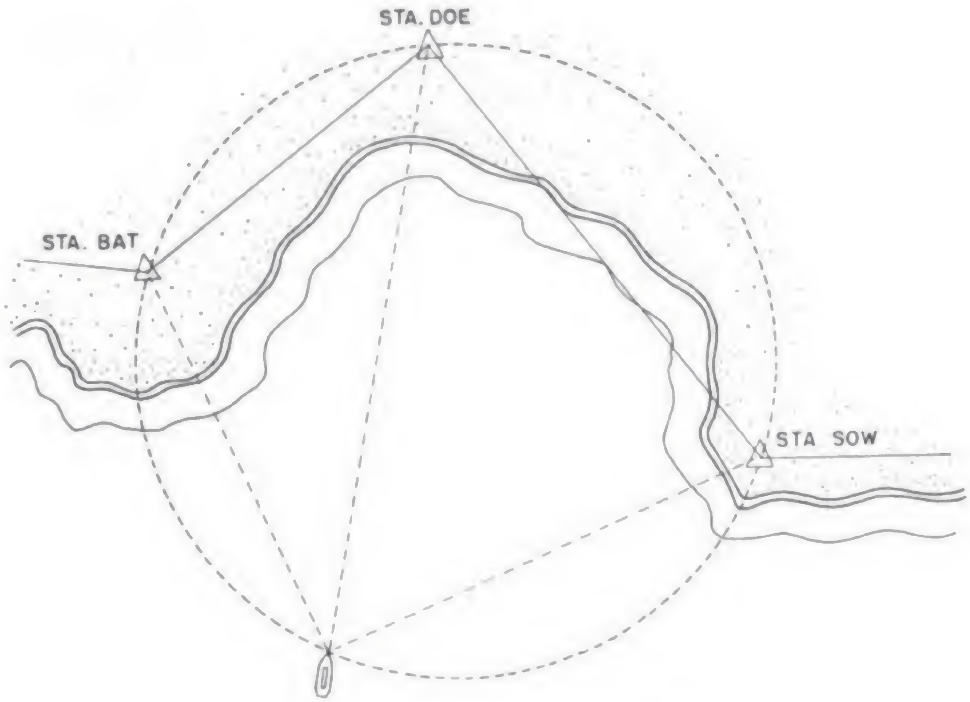


Figure 10–6.—Example of a swinger.

good judgment must be used in selecting the stations to be used for fixes.

SWEEPING of the water area in which soundings have been taken or are to be taken is an important part of most hydrographic surveys. Some form of sweep is usually used to determine whether any sizeable obstructions have been missed by individual soundings. Lead-line soundings normally give satisfactory indications of the depth in waterways when the bottom is comparatively regular, but even when taken at short intervals, they cannot be relied upon to show minimum depth over rock pinnacles, sunken wrecks, or other dangers.

SURVEYING FOR WATERFRONT STRUCTURES

After soundings have been taken to establish a good location for a natural harbor, or elevations have been taken at the shore location chosen for an artificial harbor, a plot plan is drafted of the waterfront locations selected

as adaptable. This plot plan shows the proposed construction in relation to the topography of the surrounding area and also indicates elevations throughout the construction area. Elevations for underwater areas are shown as soundings or depths below a datum. Elevations for above-water areas are shown as contours or spot elevations above a datum. A plot plan may also be referred to as a location plan.

Figure 10–7 is a plot plan of a part of a waterfront development. Dashed lines indicate proposed construction. Solid outlines show that construction is completed. Notice that one pier, a causeway, and a part of a bulkhead have been constructed. One more large pier and six smaller piers are proposed.

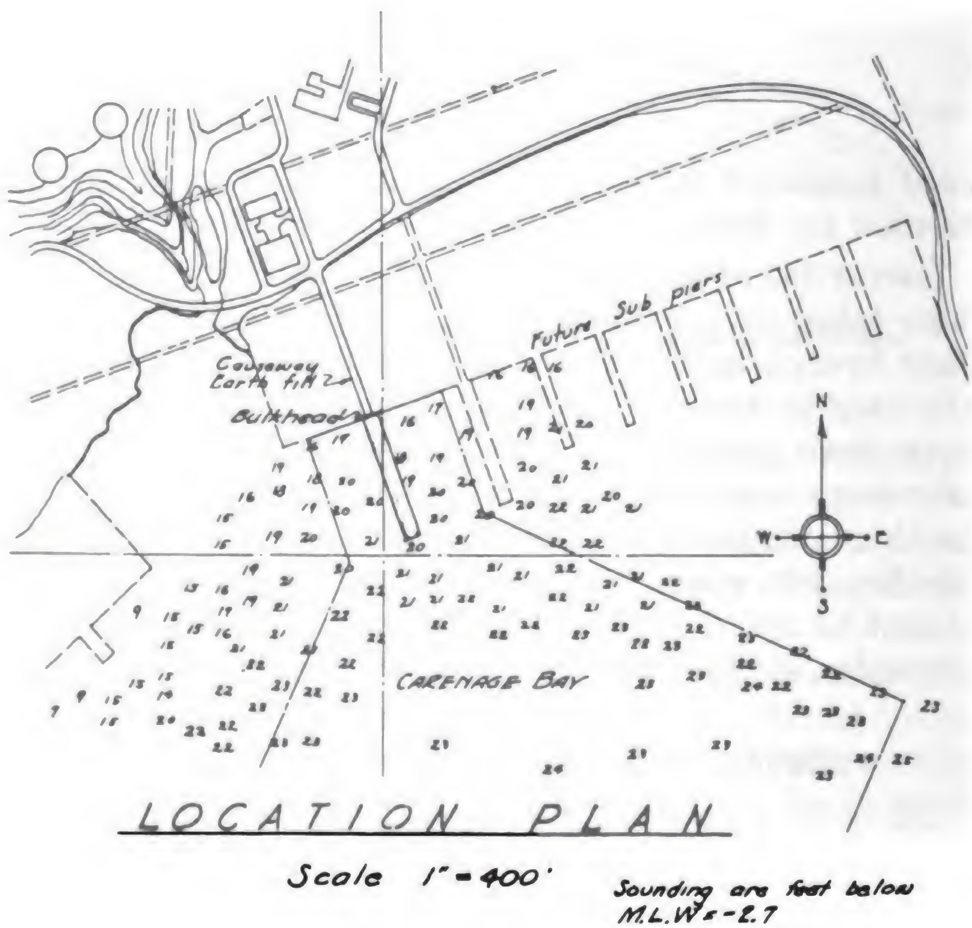


Figure 10–7.—A plot plan.

Random soundings are shown in feet below mean low water, which is given as -2.7 feet, or 2.7 feet below mean sea level. For example, a sounding at the end of the completed pier is 20 feet. The depth below mean sea level should be $20 + 2.7 = 22.7$ feet.

Occasionally you may be required to make a complete harbor layout. Figure 10–8 shows a typical one. The entrance to the harbor lies between two converging breakwaters placed to best maintain the 800-foot channel at a 42-foot M. W. depth. The various berthing facilities are situated and spaced in a manner employing to best advantage the natural and artificial features of the harbor area. The fueling facilities and tank farm are placed sufficiently far away from the other berthing areas and personnel quarters to obtain maximum safety for such areas. It is essential that such a procedure be followed in all harbor layouts.

Typical waterfront structures are piers, wharves, seawalls, breakwaters, groins, dolphins, and fenders. There

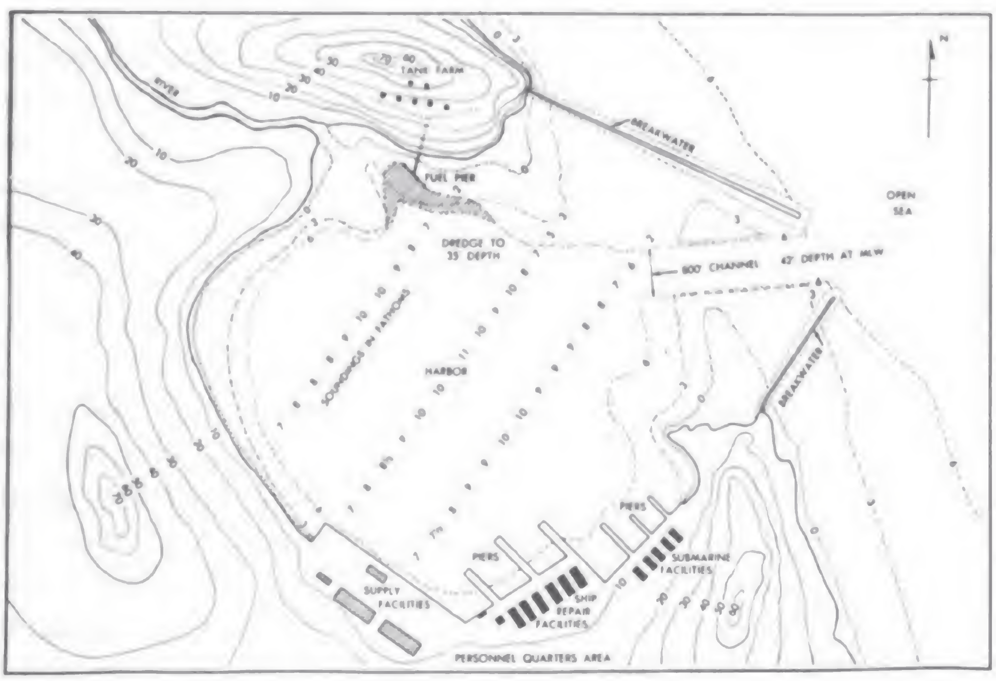


Figure 10–8.—General harbor layout.

are various procedures in surveying for location, whether it be for soundings, individual pilings, a unit of substructure, or constructions made up of rows of pilings. Examples of these structures are shown and discussed in *Waterfront and Harbor Facilities*, NavDocks TP–Pw–8. Points, units, sections, and sides must be located and aligned by means of surveys using ranges, range and chain, range and transit, transit-chain, two transits, two transits and range, three transits, or one or two sextants.

Estimating Quantities

Computations of the volumes involved are required in estimating the size of a dredging project, the time necessary to complete it, and the progress being made on the work. Several methods of calculation may be used in estimating the quantities of dredging.

VERTICAL CROSS SECTIONS.—This method is most frequently used and is best adapted to long, narrow areas such as channels or berths along the sides of wharves and canals. Sections are taken at regular intervals and volume is calculated by the average-end-area method or by the use of the prismoidal formula.

CONTOURS.—This method consists of plotting contours over the area in question and traversing each contour with a planimeter. This method gives you a series of equidistant horizontal planes from which you can compute volumes by using the average-end-area or prismoidal formula. The method is especially useful for large areas where the original ground surface is fairly regular and the cut is comparatively shallow.

EQUAL SQUARES.—This method is similar to the grid method used in borrow pit computations presented in chapter 9 of this book. It consists of dividing the area into a number of equal squares of convenient size by drawing horizontal and vertical lines on the plan. Calculate the volume from the average depth of cut in each square and record it on the plan.

SCOW MEASUREMENTS.—Volume measurements made

in place, before dredging, will generally show a volume approximately 5 to 25 percent less than that obtained by scow measurement. Thus, it is frequently desirable to convert the quantity of material measured in place to that as measured in the scows. Expansion varies with the different classes of material. Semifluid material, such as sand, has less expansion; stiff clay and hardpan show a much larger increase. Scow measurements are made by volume and by displacement.

a. BY VOLUME.—Materials removed by dipper dredge are usually loaded into scows provided with a number of pockets or hoppers. The pockets are measured, and for each scow on the project, a table of data is prepared giving the volume of each pocket when filled to various levels below the deck coaming.

b. BY DISPLACEMENT.—The weight of the material is determined by measuring the displacement of the scow before and after loading.

TIDE TABLES

The vertical rise and fall of the ocean level caused by the gravitational force between the earth and the moon (and, to a lesser extent, between the earth and the sun) is called TIDE. The highest level reached by an ascending tide is called HIGH WATER; the minimum level of a descending tide, LOW WATER. At high and low water there is a brief period during which there is no change in the water level, and this period is called STAND.

The total rise or fall from low water to high, or vice versa, is called the RANGE of the tide. The actual height of water level at high and low water varies with phases of the moon, variations of wind force and direction, and from other causes. The average height of high water measured over a period is called MEAN HIGH WATER. The average height of low water, measured in the same way, is MEAN LOW WATER. The plane midway between mean high and mean low water is MEAN SEA LEVEL. The datum for Navy installations on the Atlantic and Gulf coasts

is mean low water, and for the Pacific coast, mean low water, the average of the lower of the two daily tides. Continental leveling is based on mean sea level.

SPRING TIDES occur near the time of full moon and new moon, at which time the sun and moon act together to produce tides higher and lower than average. When the moon is in its first or last quarter, it and the sun are opposed to each other, and NEAP TIDES of less than average range occur. (See fig. 10–9.)

There are usually 2 high tides and 2 low tides each lunar day. Because of the relative positions of the sun and moon with respect to the earth and each other, there is an infinite variety of tidal situations, so that the height

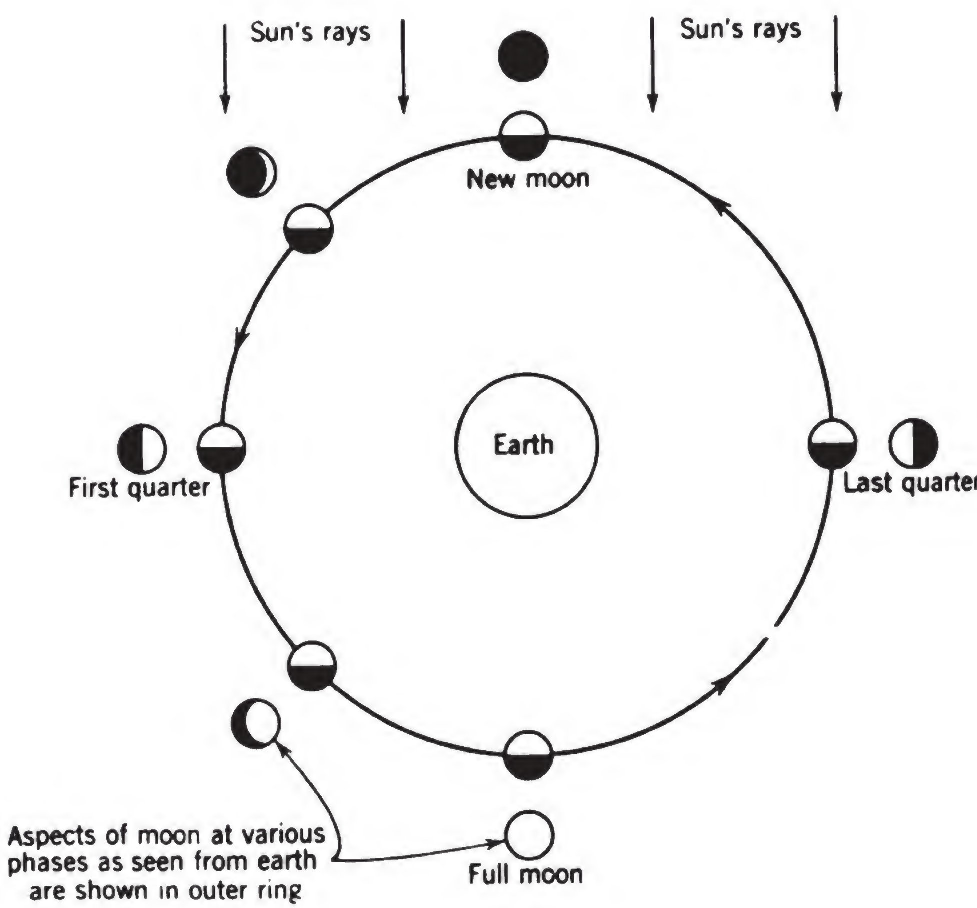


Figure 10–9.—Phases of the moon.

of the water level varies from tide to tide, and from day to day. The lower of the 2 low tides in any 1 day is called LOWER LOW WATER.

Reading the Tide Tables

The ability to read tide tables is valuable in connection with hydrographic surveys and chart construction. The following tables are published annually in advance, by the U. S. Coast and Geodetic Survey:

Tide Tables, Central and Western Pacific Ocean and Indian Ocean.

Tide Tables, East Coast North and South America (including Greenland).

Tide Tables, Europe and West Coast of Africa (including Mediterranean Sea).

Tide Tables, West Coast North and South America (including Hawaiian Islands).

Table 1 in each volume gives the time and height of tide at each high and low water for a number of principal ports, called REFERENCE STATIONS.

Because the lunar or tidal day is a little more than 24 hours in length, the time between successive high or low tides is a little more than 12 hours. Therefore, when a high or low tide occurs just before midnight, the next high or low tide will occur at about noon on the following day, and the next just after the ensuing midnight. Under these conditions, 3 consecutive high or low tides may occur on 3 different dates, the total interval involved being no longer than the period of a lunar day. When this occurs, only 1 tide is shown in table 1 for the middle day of the 3 and dots are run in, in place of the second tide.

Height of the tide has no reference to actual depth of water, nor does the charted depth shown by a sounding on a chart indicate the lowest depth to be found at all times at that particular point. MEAN LOW WATER, for example, is only an average of the various depths actually sounded there at low water during a survey. The charted

depth is the vertical distance from the reference plane, on which soundings are based, to the ocean bottom. The charted depth with this same reference plane is used as the basis for the figures for high and low water which are given in the tide tables.

As you see, the actual depth of water can be less than the charted depth, or below the reference plane. This is indicated by a minus sign placed before the height of tide shown in the tide tables. The depth of water, then, is equal to the algebraic sum of the charted depth and the height of tides as given in the tables.

Table 2 in each volume contains a list of secondary or subordinate stations. The latitude and longitude of each of these is given. Under the heading Differences, the differences in time and height of tides between the secondary stations and the reference station are listed. The time meridian and the reference station used are also given.

For example, suppose you wish to find the height of tide at George Washington Bridge in New York at 1500 on Friday 3 September 1954. First turn to table 2 in *Tide Tables, East Coast North and South America (including Greenland)* and find George Washington Bridge in the left hand column. The page on which it is found in the volume for 1954 is shown in figure 10–10. Note that New York, printed in bold type in the Differences column, is the reference station for George Washington Bridge. The time meridian is 75° W. This means that the times listed are zone times plus 5.

Now look at the headings under Differences. The time given for George Washington Bridge is plus 45 minutes, which means simply that high and low tides occur 45 minutes later at the bridge than they do at New York, the reference station. In other words, you must add 45 minutes to any time of tide given in table 1 under New York. If the sign were a minus sign, it would mean that the tide occurred earlier and you would subtract the time given from the time at the reference station.

No.	PLACE	POSITION Lat.		POSITION Long.		DIFFERENCES Time	DIFFERENCES Height High water	DIFFERENCES Height Low water	RANGES Mean	RANGES Spring
		°	′	°	′	h. m.	feet	feet	feet	feet
	NEW YORK AND NEW JERSEY—Con.									
	Hudson River‡	N.		W.		Time meridian, 75° W. on **NEW YORK**, p. 62				
838	Jersey City, Pa. R. R. Ferry, N. J.	40	43	74	02	+0 05	0.0	0.0	4.4	5.3
839	New York, Desbrosses Street	40	43	74	01	+0 10	0.0	0.0	4.4	5.3
840	New York, Chelsea Docks	40	45	74	01	+0 15	−0.1	0.0	4.3	5.2
841	Hoboken, Castle Point, N. J.	40	45	74	01	+0 15	−0.1	0.0	4.3	5.2
842	Weehawken, Days Point, N. J.	40	46	74	01	+0 25	−0.2	0.0	4.2	5.0
843	New York, Union Stock Yards	40	47	74	00	+0 25	−0.2	0.0	4.2	5.0
845	George Washington Bridge	40	51	73	57	+0 45	−0.5	0.0	3.9	4.6
847	Yonkers	40	56	73	54	+1 10	−0.8	0.0	3.6	4.2
848	Dobbs Ferry	41	01	73	53	+1 35	−1.0	0.0	3.4	4.0
849	Tarrytown	41	05	73	52	+1 50	−1.2	0.0	3.2	3.7
850	Ossining	41	10	73	52	+2 05	−1.1	+0.2	3.1	3.6
851	Haverstraw	41	12	73	58	+2 10	−1.3	+0.2	2.9	3.4
852	Peekskill	41	17	73	56	+2 25h +3 00l	−1.2	+0.3	2.9	3.4
853	West Point	41	24	73	57	+3 25	−1.4	+0.3	2.7	3.1
854	Newburgh	41	30	74	00	+3 50	−1.4	+0.2	2.8	3.2
855	New Hamburg	41	35	73	57	+4 15	−1.4	+0.1	2.9	3.3
856	Poughkeepsie	41	42	73	57	+4 35	−1.2	+0.1	3.1	3.5
857	Hyde Park	41	47	73	57	+5 00	−1.2	0.0	3.2	3.6
858	Kingston Point	41	56	73	58	+5 25	−0.8	−0.1	3.7	4.2
859	Tivoli	42	04	73	56	+5 55	−0.7	−0.2	3.9	4.4
860	Catskill	42	13	73	51	+6 45	−0.6	−0.3	4.1	4.6
861	Hudson	42	15	73	48	+7 00	−0.8	−0.4	4.0	4.4
						on **ALBANY**, p. 66				
862	Coxsackie	42	21	73	48	−1 00h −1 40l	−0.5	+0.2	3.9	4.3
863	New Baltimore	42	27	73	47	−0 45	−0.1	+0.4	4.1	4.5
864	Castleton-on-Hudson	42	32	73	46	−0 25	−0.2	+0.1	4.3	4.7
865	**Albany**	42	39	73	45	Daily predictions			4.6	5.0
866	Troy	42	44	73	42	+0 10	+0.1	0.0	4.7	5.1
	The Kills and Newark Bay					on **NEW YORK**, p. 62				
	Kill Van Kull									
867	Constable Hook	40	39	74	05	−0 15	+0.1	0.0	4.5	5.4
868	New Brighton	40	39	74	05	−0 15	+0.1	0.0	4.5	5.4
869	Port Richmond	40	38	74	08	0 00	+0.1	0.0	4.5	5.4
870	Bergen Point	40	39	74	08	+0 05	+0.2	0.0	4.6	5.5
871	Shooters Island	40	39	74	10	+0 10	+0.2	0.0	4.6	5.5
872	Port Newark Terminal	40	42	74	09	+0 30	+0.6	0.0	5.0	6.0
873	Newark, Passaic River	40	44	74	10	+0 35h +1 10l	+0.7	0.0	5.1	6.1
874	Passaic, Gregory Ave. bridge, Passaic River	40	51	74	07	+0 50h +1 55l	+0.7	0.0	5.1	6.1
875	Little Ferry, Hackensack River	40	51	74	02	+1 30	+0.9	0.0	5.3	6.4
876	Hackensack, Hackensack River	40	53	74	02	+1 45	+0.9	0.0	5.3	6.4
	Arthur Kill					on **SANDY HOOK**, p. 70				
877	Elizabethport	40	39	74	11	+1 00	+0.2	0.0	4.8	5.8
878	Chelsea	40	36	74	12	+0 50	+0.4	0.0	5.0	6.0

‡Values for the Hudson River above George Washington Bridge are based upon averages for the six months May to October, when the fresh-water discharge is a minimum.
h = difference for high waters only.
l = difference for low waters only.

Figure 10–10.—A portion of the table of tidal differences and ranges.

JULY

Day	High Time	High Ht.	Low Time	Low Ht.
	h. m.	ft.	h. m.	ft.
1	8 45	4.5	2 47	-0.6
Th	21 01	5.6	14 52	-0.2
2	9 38	4.5	3 32	-0.6
F	21 51	5.3	15 40	-0.1
3	10 31	4.5	4 17	-0.5
Sa	22 40	5.0	16 27	0.1
4	11 22	4.5	5 00	-0.3
Su	23 27	4.7	17 13	0.4
5	. ..	. .	5 42	0.0
M	12 09	4.4	18 03	0.7
6	0 13	4.4	6 28	0.2
Tu	12 54	4.4	19 00	1.0
7	0 56	4.1	7 18	0.5
W	13 39	4.3	20 03	1.1
8	1 39	3.8	8 14	0.6
Th	14 24	4.3	21 05	1.1
9	2 26	3.6	9 08	0.8
F	15 12	4.3	22 01	1.0
10	3 21	3.5	9 59	0.8
Sa	16 05	4.4	22 51	0.8
11	4 26	3.4	10 46	0.7
Su	17 00	4.6	23 39	0.6
12	5 27	3.5	11 33	0.7
M	17 49	4.8	. ..	. .
13	6 19	3.7	0 27	0.4
Tu	18 33	5.0	12 20	0.6
14	7 04	3.9	1 14	0.2
W	19 14	5.1	13 06	0.5
15	7 45	4.0	1 57	0.0
Th	19 53	5.3	13 52	0.3
16	8 25	4.2	2 38	-0.2
F	20 31	5.3	14 35	0.2
17	9 06	4.4	3 17	-0.3
Sa	21 12	5.2	15 16	0.1
18	9 50	4.5	3 53	-0.4
Su	21 56	5.1	15 57	0.1
19	10 37	4.7	4 29	-0.3
M	22 44	5.0	16 39	0.1
20	11 27	4.8	5 07	-0.2
Tu	23 36	4.8	17 27	0.2
21	. ..	. .	5 50	-0.1
W	12 18	4.9	18 26	0.4
22	0 28	4.5	6 42	0.1
Th	13 11	5.0	19 40	0.6
23	1 24	4.3	7 50	0.2
F	14 07	5.1	20 56	0.6
24	2 26	4.1	9 00	0.3
Sa	15 09	5.1	22 02	0.4
25	3 35	4.0	10 04	0.3
Su	16 17	5.2	23 01	0.2
26	4 49	4.0	11 03	0.2
M	17 22	5.3	23 57	0.0
27	5 55	4.2	. ..	. .
Tu	18 20	5.5	12 00	0.1
28	6 51	4.4	0 50	-0.2
W	19 10	5.6	12 55	0.0
29	7 40	4.6	1 40	-0.3
Th	19 57	5.5	13 47	-0.1
30	8 28	4.7	2 26	-0.4
F	20 41	5.4	14 36	-0.1
31	9 14	4.8	3 09	-0.5
Sa	21 25	5.2	15 21	0.0

AUGUST

Day	High Time	High Ht.	Low Time	Low Ht.
	h. m.	ft.	h. m.	ft.
1	9 59	4.7	3 [illegible]	-0.4
Su	22 08	4.9	16 [illegible]	[illegible]
2	10 44	4.7	4 27	[illegible]
M	22 50	4.6	16 43	[illegible]
3	11 28	4.6	5 03	0.0
Tu	23 32	4.3	17 25	0.7
4	. ..	. .	5 38	0.3
W	12 09	4.5	18 10	1.0
5	0 11	4.0	6 16	0.6
Th	12 50	4.4	19 08	1.2
6	0 51	3.8	7 04	0.9
F	13 31	4.3	20 17	1.3
7	1 35	3.6	8 10	1.1
Sa	14 17	4.3	21 21	1.2
8	2 30	3.4	9 16	1.1
Su	15 12	4.3	22 17	1.1
9	3 38	3.4	10 12	1.1
M	16 14	4.5	23 08	0.8
10	4 49	3.5	11 04	0.9
Tu	17 13	4.7	23 55	0.5
11	5 47	3.8	11 53	0.7
W	18 04	4.9	. ..	. .
12	6 35	4.1	0 41	0.3
Th	18 48	5.2	12 41	0.4
13	7 17	4.4	1 25	0.0
F	19 30	5.4	13 29	0.2
14	7 57	4.7	2 07	-0.3
Sa	20 10	5.4	14 14	-0.1
15	8 37	5.0	2 47	-0.4
Su	20 52	5.4	14 58	-0.2
16	9 21	5.2	3 26	-0.5
M	21 37	5.3	15 41	-0.3
17	10 09	5.3	4 04	-0.5
Tu	22 27	5.1	16 26	-0.2
18	11 02	5.3	4 43	-0.4
W	23 20	4.8	17 14	0.0
19	11 56	5.3	5 26	-0.1
Th	. ..	. .	18 11	0.3
20	0 16	4.5	6 19	0.2
F	12 53	5.2	19 23	0.5
21	1 14	4.2	7 30	0.4
Sa	13 52	5.1	20 40	0.6
22	2 19	4.0	8 47	0.6
Su	14 57	5.0	21 48	0.5
23	3 29	3.9	9 55	0.5
M	16 06	5.0	22 48	0.3
24	4 41	4.0	10 55	0.4
Tu	17 11	5.1	23 40	0.1
25	5 44	4.3	11 50	0.2
W	18 07	5.2	. ..	. .
26	6 37	4.6	0 30	-0.1
Th	18 55	5.3	12 42	0.1
27	7 23	4.8	1 17	-0.2
F	19 38	5.3	13 31	0.0
28	8 05	4.9	2 00	-0.3
Sa	20 19	5.2	14 17	0.0
29	8 45	5.0	2 40	-0.3
Su	20 57	5.0	14 59	0.0
30	9 24	4.9	3 19	-0.2
M	21 34	4.7	15 37	0.1
31	10 02	4.8	3 52	-0.1
Tu	22 10	4.5	16 15	0.3

SEPTEMBER

Day	High Time	High Ht.	Low Time	Low Ht.
	h. m.	ft.	h. m.	ft.
1	10 40	4.7	4 24	0.2
W	22 47	4.2	16 51	0.6
2	11 18	4.6	4 52	0.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	11 57	4.4	5 17	0.7
F	. ..	. .	18 13	1.1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sa	12 37	4.3	19 20	1.3
5	0 49	3.5	6 27	1.2
Su	13 23	4.3	20 38	1.3
6	1 45	3.4	8 21	1.4
M	14 18	4.3	21 41	1.1
7	2 56	3.4	9 38	1.2
Tu	15 24	4.4	22 33	0.9
8	4 10	3.6	10 35	1.0
W	16 31	4.6	23 21	0.6
9	5 13	4.0	11 26	0.6
Th	17 29	4.8	. ..	. .
10	6 02	4.4	0 06	0.2
F	18 19	5.1	12 16	0.3
11	6 46	4.8	0 49	-0.1
Sa	19 03	5.3	13 04	-0.1
12	7 27	5.2	1 32	-0.4
Su	19 46	5.4	13 51	-0.4
13	8 10	5.5	2 14	-0.6
M	20 30	5.4	14 36	-0.6
14	8 54	5.7	2 55	-0.6
Tu	21 16	5.2	15 24	-0.6
15	9 43	5.7	3 36	-0.6
W	22 08	5.0	16 11	-0.5
16	10 37	5.6	4 19	-0.5
Th	23 06	4.7	17 00	-0.2
17	11 36	5.4	5 06	-0.2
F	. ..	. .	17 57	0.1
18	0 07	4.4	6 01	0.2
Sa	12 36	5.2	19 07	0.4
19	1 09	4.1	7 16	0.6
Su	13 38	5.0	20 23	0.5
20	2 14	4.0	8 37	0.7
M	14 42	4.8	21 31	0.5
21	3 22	4.0	9 46	0.6
Tu	15 49	4.7	22 28	0.3
22	4 29	4.1	10 44	0.5
W	16 53	4.8	23 19	0.1
23	5 28	4.4	11 36	0.3
Th	17 47	4.8	. ..	. .
24	6 18	4.7	0 05	0.0
F	18 34	4.9	12 26	0.2
25	7 00	4.9	0 49	-0.1
Sa	19 15	4.9	13 11	0.0
26	7 38	5.1	1 30	-0.2
Su	19 53	4.8	13 54	0.0
27	8 15	5.1	2 09	-0.2
M	20 28	4.7	14 35	0.0
28	8 49	5.1	2 46	-0.1
Tu	21 02	4.5	15 13	0.1
29	9 23	4.9	3 20	0.1
W	21 35	4.2	15 48	0.2
30	9 55	4.8	3 50	0.3
Th	22 08	4.0	16 24	0.4

Time meridian 75° W. The hours of the day are numbered consecutively from 0^h (midnight) to 23^h (11 00 p.m.). 12^h is noon. All hours greater than 12 are in the afternoon (p.m.).

Heights are reckoned from the datum of soundings on charts of the locality which is mean low water.

Figure 10–11.—A page from the table of reference stations.

Under Height, High Water is the figure -0.5. This means that the height of high water at the George Washington Bridge is 0.5 foot less than the height of high water at New York, the reference station. Height of low water is listed as 0.0, indicating that no adjustment need be made in the height of low water under the reference station. A plus (+) sign always indicates that the difference should be added to the height at the reference station and a minus (—) sign that it should be subtracted.

Now you have the differences you need to apply to the data on the reference station in table 1. Page 62 from that table is shown in figure 10–11. Running down the column for September, find the date 3 F (Friday) and note that at New York a high water will occur at 1157 and a low water at 1813 on that date. Applying the difference (plus 45 minutes) from table 2 for George Washington Bridge, you find that high tide occurs at 1242 and low tide at 1858 at the bridge.

Since 1500 comes after the time of high water, you know that the tide is falling (ebbing) at the time. By subtracting 1242 from 1858, you find that it takes 6 hours and 16 minutes for the tide to go all the way out at the bridge. By subtracting 1242 from 1500, you learn that the time you are concerned with is 2 hours and 18 minutes past high water.

Table 1 tells you that the height of high water at the reference station is 4.4 feet. From table 2, you learn that the height of high water at George Washington Bridge is 0.5 feet less than that at the reference station. Therefore, height of high water at the bridge is 3.9 feet. Height of low water at New York is 1.1. Subtract this from 3.9 feet (height of high water) and you find that the range of the tide at the bridge is 2.8 feet.

Now turn to table 3, a table which makes it possible for you to find the height of the tide at any time. (See fig. 10–12.) You know that the duration of the fall in this case is 6 hours and 16 minutes and that the time

	Time from the nearest high water or low water														
h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
4 00	0 08	0 16	0 24	0 32	0 40	0 48	0 56	1 04	1 12	1 20	1 28	1 36	1 44	1 52	2 00
4 20	0 09	0 17	0 26	0 35	0 43	0 52	1 01	1 09	1 18	1 27	1 35	1 44	1 53	2 01	2 10
4 40	0 09	0 19	0 28	0 37	0 47	0 56	1 05	1 15	1 24	1 33	1 43	1 52	2 01	2 11	2 20
5 00	0 10	0 20	0 30	0 40	0 50	1 00	1 10	1 20	1 30	1 40	1 50	2 00	2 10	2 20	2 30
5 20	0 11	0 21	0 32	0 43	0 53	1 04	1 15	1 25	1 36	1 47	1 57	2 08	2 19	2 29	2 40
5 40	0 11	0 23	0 34	0 45	0 57	1 08	1 19	1 31	1 42	1 53	2 05	2 16	2 27	2 39	2 50
6 00	0 12	0 24	0 36	0 48	1 00	1 12	1 24	1 36	1 48	2 00	2 12	2 24	2 36	2 48	3 00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2 32	2 45	2 57	3 10
6 40	0 13	0 27	0 40	0 53	1 07	1 20	1 33	1 47	2 00	2 13	2 27	2 40	2 53	3 07	3 20
7 00	0 14	0 28	0 42	0 56	1 10	1 24	1 38	1 52	2 06	2 20	2 34	2 48	3 02	3 16	3 30
7 20	0 15	0 29	0 44	0 59	1 13	1 28	1 43	1 57	2 12	2 27	2 41	2 56	3 11	3 25	3 40
7 40	0 15	0 31	0 46	1 01	1 17	1 32	1 47	2 03	2 18	2 33	2 49	3 04	3 19	3 35	3 50
8 00	0 16	0 32	0 48	1 04	1 20	1 36	1 52	2 08	2 24	2 40	2 56	3 12	3 28	3 44	4 00
8 20	0 17	0 33	0 50	1 07	1 23	1 40	1 57	2 13	2 30	2 47	3 03	3 20	3 37	3 53	4 10
8 40	0 17	0 35	0 52	1 09	1 27	1 44	2 01	2 19	2 36	2 53	3 11	3 28	3 45	4 03	4 20
9 00	0 18	0 36	0 54	1 12	1 30	1 48	2 06	2 24	2 42	3 00	3 18	3 36	3 54	4 12	4 30
9 20	0 19	0 37	0 56	1 15	1 33	1 52	2 11	2 29	2 48	3 07	3 25	3 44	4 03	4 21	4 40
9 40	0 19	0 39	0 58	1 17	1 37	1 56	2 15	2 35	2 54	3 13	3 33	3 52	4 11	4 31	4 50
10 00	0 20	0 40	1 00	1 20	1 40	2 00	2 20	2 40	3 00	3 20	3 40	4 00	4 20	4 40	5 00
10 20	0 21	0 41	1 02	1 23	1 43	2 04	2 25	2 45	3 06	3 27	3 47	4 08	4 29	4 49	5 10
10 40	0 21	0 43	1 04	1 25	1 47	2 08	2 29	2 51	3 12	3 33	3 55	4 16	4 37	4 59	5 20

Duration of rise or fall, see footnote

	Correction to height														
Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
1.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5
1.5	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8
2.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
2.5	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.0	1.2	1.3	1.5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.2	1.4	1.6	1.8
4.0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.6	1.8	2.0
4.5	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.3	1.6	1.8	2.0	2.2
5.0	0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.8	1.0	1.2	1.5	1.7	2.0	2.2	2.5
5.5	0.0	0.1	0.1	0.2	0.4	0.5	0.7	0.9	1.1	1.4	1.6	1.9	2.2	2.5	2.8
6.0	0.0	0.1	0.1	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.8	2.1	2.4	2.7	3.0
6.5	0.0	0.1	0.2	0.3	0.4	0.6	0.8	1.1	1.3	1.6	1.9	2.2	2.6	2.9	3.2
7.0	0.0	0.1	0.2	0.3	0.5	0.7	0.9	1.2	1.4	1.8	2.1	2.4	2.8	3.1	3.5
7.5	0.0	0.1	0.2	0.3	0.5	0.7	1.0	1.2	1.5	1.9	2.2	2.6	3.0	3.4	3.8
8.0	0.0	0.1	0.2	0.3	0.5	0.8	1.0	1.3	1.6	2.0	2.4	2.8	3.2	3.6	4.0
8.5	0.0	0.1	0.2	0.4	0.6	0.8	1.1	1.4	1.8	2.1	2.5	2.9	3.4	3.8	4.2
9.0	0.0	0.1	0.2	0.4	0.6	0.9	1.2	1.5	1.9	2.2	2.7	3.1	3.6	4.0	4.5
9.5	0.0	0.1	0.2	0.4	0.6	0.9	1.2	1.6	2.0	2.4	2.8	3.3	3.8	4.3	4.8
10.0	0.0	0.1	0.2	0.4	0.7	1.0	1.3	1.7	2.1	2.5	3.0	3.5	4.0	4.5	5.0
10.5	0.0	0.1	0.3	0.5	0.7	1.0	1.3	1.7	2.2	2.6	3.1	3.6	4.2	4.7	5.2
11.0	0.0	0.1	0.3	0.5	0.7	1.1	1.4	1.8	2.3	2.8	3.3	3.8	4.4	4.9	5.5
11.5	0.0	0.1	0.3	0.5	0.8	1.1	1.5	1.9	2.4	2.9	3.4	4.0	4.6	5.1	5.8
12.0	0.0	0.1	0.3	0.5	0.8	1.1	1.5	2.0	2.5	3.0	3.6	4.1	4.8	5.4	6.0
12.5	0.0	0.1	0.3	0.5	0.8	1.2	1.6	2.1	2.6	3.1	3.7	4.3	5.0	5.6	6.2
13.0	0.0	0.1	0.3	0.6	0.9	1.2	1.7	2.2	2.7	3.2	3.9	4.5	5.1	5.8	6.5
13.5	0.0	0.1	0.3	0.6	0.9	1.3	1.7	2.2	2.8	3.4	4.0	4.7	5.3	6.0	6.8
14.0	0.0	0.2	0.3	0.6	0.9	1.3	1.8	2.3	2.9	3.5	4.2	4.8	5.5	6.3	7.0
14.5	0.0	0.2	0.4	0.6	1.0	1.4	1.9	2.4	3.0	3.6	4.3	5.0	5.7	6.5	7.2
15.0	0.0	0.2	0.4	0.6	1.0	1.4	1.9	2.5	3.1	3.8	4.4	5.2	5.9	6.7	7.5
15.5	0.0	0.2	0.4	0.7	1.0	1.5	2.0	2.6	3.2	3.9	4.6	5.4	6.1	6.9	7.8
16.0	0.0	0.2	0.4	0.7	1.1	1.5	2.1	2.6	3.3	4.0	4.7	5.5	6.3	7.2	8.0
16.5	0.0	0.2	0.4	0.7	1.1	1.6	2.1	2.7	3.4	4.1	4.9	5.7	6.5	7.4	8.2
17.0	0.0	0.2	0.4	0.7	1.1	1.6	2.2	2.8	3.5	4.2	5.0	5.9	6.7	7.6	8.5
17.5	0.0	0.2	0.4	0.8	1.2	1.7	2.2	2.9	3.6	4.4	5.2	6.0	6.9	7.8	8.8
18.0	0.0	0.2	0.4	0.8	1.2	1.7	2.3	3.0	3.7	4.5	5.3	6.2	7.1	8.1	9.0
18.5	0.1	0.2	0.5	0.8	1.2	1.8	2.4	3.1	3.8	4.6	5.5	6.4	7.3	8.3	9.2
19.0	0.1	0.2	0.5	0.8	1.3	1.8	2.4	3.1	3.9	4.8	5.6	6.6	7.5	8.5	9.5
19.5	0.1	0.2	0.5	0.8	1.3	1.9	2.5	3.2	4.0	4.9	5.8	6.7	7.7	8.7	9.8
20.0	0.1	0.2	0.5	0.9	1.3	1.9	2.6	3.3	4.1	5.0	5.9	6.9	7.9	9.0	10.0

Range of tide, see footnote

Obtain from the predictions the high water and low water, one of which is before and the other after the time for which the height is required. The difference between the times of occurrence of these tides is the duration of rise or fall, and the difference between their heights is the range of tide for the above table. Find the difference between the nearest high or low water and the time for which the height is required.

Enter the table with the duration of rise or fall, printed in heavy-faced type, which most nearly agrees with the actual value, and on that horizontal line find the time from the nearest high or low water which agrees most nearly with the corresponding actual difference. The correction sought is in the column directly below, on the line with the range of tide.

When the nearest tide is high water, subtract the correction.

When the nearest tide is low water, add the correction.

Figure 10-12.—Height of tide at any time.

from the nearest high water is 2 hours and 18 minutes past high water. The nearest value to 6 hours and 16 minutes is found to be 6 hours and 20 minutes. Enter the table on this line and run across to 2 hours and 19 minutes.

Now run down this column to the Correction to Height part of the table. You know that the range at the bridge is 2.8 feet. Where the 3.0 range line, the nearest range on the table to 2.8, intersects the Time From the Nearest High Water column, read 0.9 feet. This is the amount the tide will have fallen below high by 1500, 2 hours and 18 minutes past high water. By subtracting this from the height of high water at the bridge (3.9 feet), you learn that 3.0 feet will be the approximate height of the tide above the charted depth at the bridge at 1500.

For some stations in table 2, height differences would give unsatisfactory predictions. In such cases, the height differences have been omitted and 1 or 2 ratios are given instead. Where 2 ratios are given, 1 in the Height of High Water column and 1 in the Height of Low Water column, the high waters and low waters at the reference station should be multiplied by these respective ratios. Where only one is given, the omitted ratio is either unreliable or unknown.

CURRENT TABLES

A tidal current is the result of a tide, but not the tide itself. Tidal current is the horizontal motion of water resulting from the vertical motion caused by tide. Tidal currents are so called to distinguish them from ocean or river currents.

The horizontal motion of water toward the land caused by a rising tide is called FLOOD CURRENT; the horizontal motion away from the land caused by a falling tide, EBB CURRENT. Between these two, while the current is changing direction, there is a brief period when no horizontal motion is perceptible. This is called SLACK WATER.

The change of direction of the current always lags behind the time of turning of the tide, by an interval which varies in length according to the physical characteristics of the land around the body of tidewater. For instance, along a relatively straight coast with only shallow indentations, there is usually little difference between the time of high or low water and the time of slack water.

But where a large bay connects with the ocean through a narrow channel, the tide and the current may be out of phase by as much as 3 hours. In a case like this, the current in the channel may be running at its greatest velocity when it is high or low water outside. The direction of a tidal current is called SET and the velocity is called DRIFT.

Reading Current Tables

Current tables are published annually by the Coast and Geodetic Survey. Like the tide tables, they are divided into a table for reference stations (table 1) and a table for subordinate stations (table 2). Table 1 lists predicted times of slack water and predicted times and velocities of maximum flood and ebb at the reference stations for each day of the year.

In table 2, the latitude and longitude of each subordinate station are given, together with difference in time of current and a velocity ratio with respect to one of the reference stations. Like the tidal difference in time, the current time difference is applied to the time of slack or strength at the reference station to get the corresponding time at the subordinate station. Velocity at the subordinate station is found by multiplying velocity at the reference station by the listed velocity ratio.

Also included in table 2 is information concerning flood interval, flood direction, average velocity, and spring velocity at strength of current. As you know, the flood tide is caused by the moon's attraction. In other words, as the moon passes over the meridian, the water piles

up in its wake. The flood interval is the time which elapses between the moon's meridian transit and the ensuing maximum flood current. Maximum ebb will occur approximately 6¼ hours earlier or later.

Flood direction is the true direction of the set of the current at maximum flood. The set of maximum ebb is generally pretty close to the opposite of the flood direction.

Average velocity given is the mean of all maximum flood and ebb currents. Spring velocity is the mean of the strength of flood and ebb currents at the time of spring tides.

Table 3 in the current tables is like table 3 in the tide tables. It is used to find the velocity of the current at a specific time.

Now, let's see if we can determine the set and drift of the current at the George Washington Bridge, for the same time (1500) on the same day for which we predicted the height of the tide. First, find George Washington Bridge in table 2 of the *Current Tables, Atlantic Coast, North America*. The page from this table in the 1954 volume is shown in figure 10–13. Note that the current reference station for George Washington Bridge is The Narrows, shown in boldface type near the top of the page.

Now notice that the time difference shown opposite is plus 1 hour and 55 minutes. This means that when certain current conditions exist at The Narrows, the same conditions will exist 1 hour and 55 minutes later at the bridge. Velocity ratio, as you see, is 1.1. This means that, if the current flows at a certain rate at The Narrows, it will be flowing 1.1 times as fast at the bridge 1 hour and 55 minutes later.

Under the heading At Strength of Current, you see four columns. The first is Flood Interval. This, as already explained, is the average number of hours and minutes after the moon transits the meridian that maximum flood

Station or locality	Latitude	Longitude	Time difference	Velocity ratio	At strength of current: Flood interval	Flood direction (true)	Average velocity	Spring velocity
	° ′ North	° ′ West	h. m.		h. m.	Deg.	Knots	Knots
Long Island, South Coast			*Time meridian, 75° W.*					
	Reference station, **The Narrows,** New York Harbor, p. 52							
Fire Island Lighted Whistle Buoy 2FI*	40 29	73 11	.....	.....	.....	.....	.....	.....
Fire Island Inlet, 22 miles south of [1]	40 16	73 16	.....	.....	.....	.....	.....	.....
Shinnecock Canal, railroad bridge	40 53	72 30	[2] −0 40	[2] 0.8	.....	[2] 180	[2] 1.5	.....
Ponquogue bridge, Shinnecock Bay	40 51	72 30	+0 40	0.4	7 40	250	0.7	0.8
Shinnecock Inlet	40 51	72 29	−0 20	1.3	6 30	350	2.4	2.9
Fire Island Inlet, inside, near Democrat Pt	40 38	73 17	−0 20	1.3	6 35	115	2.3	2.8
Jones Inlet	40 35	73 34	−1 00	1.6	5 55	35	2.9	3.5
Long Beach, inside, between bridges	40 36	73 40	0 00	0.3	6 55	75	0.6	0.7
East Rockaway Inlet	40 35	73 45	−1 30	1.3	5 25	40	2.3	2.8
Ambrose Channel Lightship*	40 27	73 49	.....	.....	.....	.....	.....	.....
Scotland Lightship*	40 27	73 55	.....	.....	.....	.....	.....	.....
Jamaica Bay								
Rockaway Inlet	40 34	73 56	−2 00	1.2	4 55	85	2.2	2.6
East of Barren Island	40 35	73 53	−2 10	0.8	4 40	5	1.5	1.8
Canarsie (midchannel, off pier)	40 38	73 53	−1 45	0.3	5 10	45	0.6	0.7
Beach Channel (bridge)	40 35	73 49	−1 20	1.1	5 35	60	1.9	2.3
Grass Hassock Chan., off Little Bay Marsh	40 37	73 47	−1 05	0.6	5 50	50	1.0	1.2
New York Harbor Entrance								
Ambrose Channel entrance	40 30	73 58	−1 05	1.1	5 45	300	2.0	2.4
Ambrose Channel, SE. of West Bank Light	40 32	74 01	([3])	0.8	5 55	310	1.5	1.8
Ambrose Channel, north end	40 34	74 02	+0 10	0.9	7 05	330	1.6	1.9
Coney Island, ¼ mile west of	40 35	74 01	−0 55	0.9	6 00	330	1.7	2.0
Ft. Lafayette, channel east of	40 36	74 02	[4] −2 00	0.6	6 50	345	1.0	1.2
The Narrows, midchannel	40 37	74 03	.....	.....	6 55	340	1.8	2.2
Upper Bay, New York Harbor								
Tompkinsville	40 38	74 04	+0 05	1.0	6 55	5	1.8	2.2
Bay Ridge Channel	40 39	74 02	−0 40	0.6	6 15	40	1.1	1.3
Red Hook Channel	40 40	74 01	−0 30	0.7	6 25	10	1.2	1.4
Robbins Reef Light, east of	40 39	74 03	+0 15	0.8	7 05	15	1.5	1.8
Red Hook, 1 mile west of	40 41	74 02	+0 50	1.0	7 45	25	1.8	2.2
Statue of Liberty, east of	40 42	74 02	+0 55	1.1	7 50	30	2.0	2.4
Hudson River, Midchannel [5]								
The Battery, northwest of	40 43	74 02	+1 35	1.1	8 25	15	1.9	2.3
Desbrosses Street	40 43	74 01	+1 35	1.1	8 30	10	1.9	2.3
Chelsea Docks	40 45	74 01	+1 35	1.1	8 35	10	1.9	2.3
Forty-second Street	40 46	74 00	+1 40	1.1	8 40	30	2.0	2.4
Ninety-sixth Street	40 48	73 59	+1 45	1.1	8 45	30	2.0	2.4
George Washington Bridge	40 51	73 57	+1 55	1.1	8 45	20	1.9	2.3
Riverdale	40 54	73 55	+2 15	0.9	9 05	15	1.7	2.0
Dobbs Ferry	41 01	73 53	+2 35	0.8	9 30	10	1.5	1.8

*See table 5.

[1] Tidal current is weak averaging about 0.1 knot at maximum.

[2] For maximum southward current only, the gates of the lock being closed to prevent northward flow. Apply difference and ratio to maximum ebb at The Narrows.

[3] Current is rotary, turning clockwise. Time difference for maximum flood, $-1^h\,00^m$; maximum ebb, $+0^h\,15^m$ (direction 170°). Minimum current of 0.9 knot sets SW. about time of "Slack, flood begins" at The Narrows. Minimum current of 0.5 knot sets NE. about 1 hour before "Slack, ebb begins" at The Narrows.

[4] Time difference for maximum ebb and beginning of flood. Maximum flood and beginning of ebb occur about the same time as in The Narrows.

[5] The values for the Hudson River are for the summer months, when the fresh-water discharge is a minimum.

Figure 10–13.—Current differences and constants.

current will occur. Maximum ebb will be 6 hours later or earlier.

Direction (or set) of the flood current (20° true) is given in the next column. Unless the tables state otherwise, you can assume that direction of the ebb current will be the reciprocal (180° plus). The next column gives average velocity and the last column spring velocity.

You now have all the values you must apply to the reference station data in order to determine conditions at the subordinate station. These are:

Time difference:	plus 1 h 55m.
Velocity ratio:	1.1.
Flood direction:	20° true.

Turn to table 1, The Narrows, and find Friday, 3 September, as shown in figure 10–14. You want to know the set (direction) and the drift (velocity) of the current at George Washington Bridge at 1500.

First, is the current ebbing or flowing at this time? Ebbing begins at the reference station at 1344, and the difference is plus 1 hour 55 minutes. Consequently, ebbing begins at the bridge at 1344 plus 1 hour 55 minutes, or 1539. So at 1500 the current is still flooding.

The interval between maximum current and slack is 3 hours and 8 minutes, and the interval between 1500 and slack is 39 minutes. Velocity of the maximum ebb at the reference station is 1.7 knots, and the velocity ratio at the bridge is 1.1 times that, or 1.87.

Now turn to table 3, shown in figure 10–15, and figure out the velocity of the current at the bridge at 1500. You enter the table with the interval between slack and minimum current (3h 9m) and the interval between slack and minimum current (39m). The value in the column headings of the table which is closest to the first is 3 hours and no minutes (3h 00m); the value closest to the second in the left hand column is 40 minutes (0h 40m). Where

Day	Slack; Flood Begins	Maximum Flood		Slack; Ebb Begins	Maximum Ebb	
SEPTEMBER						
	Time	Time	Velocity	Time	Time	Velocity
	h. m.	h. m.	kn.	h. m.	h. m.	kn.
1 W	[illegible]3 [illegible]9	9 01 21 23	1.7 1.3	. .. 12 15	3 04 15 29	2.0 1.9
2 [illegible]	[illegible]15 [illegible]	9 47 [illegible]	1.6 [illegible]	0 24 [illegible]	3 41 [illegible]	1.8 [illegible]
3 F	8 01 20 59	10 35 23 00	1.5 1.1	1 05 13 44	4 22 17 00	1.7 1.6
[illegible] Sa	[illegible] 21 55	[illegible] 23 50	[illegible] 1.0	[illegible] 14 33	[illegible] 17 57	[illegible] 1.5
5 Su	9 49 22 52	. .. 12 13	. . 1.4	2 39 15 27	6 08 19 02	1.4 1.5
6 M	10 43 23 45	0 41 13 04	0.9 1.4	3 36 16 27	7 14 20 00	1.4 1.6
7 Tu	11 40 . ..	1 38 14 01	0.9 1.4	4 38 17 26	8 13 20 52	1.5 1.7
8 W	0 36 12 32	2 39 15 01	1.0 1.5	5 39 18 21	9 05 21 40	1.6 1.8
9 Th	1 24 13 26	3 37 16 00	1.2 1.7	6 34 19 09	9 53 22 25	1.8 2.0
10 F	2 08 14 17	4 30 16 51	1.5 1.8	7 23 19 54	10 40 23 11	2.0 2.1
11 Sa	2 49 15 04	5 14 17 36	1.8 2.0	8 11 20 38	11 30 23 58	2.2 2.3
12 Su	3 28 15 50	5 57 18 18	2.0 2.1	8 58 21 22	. .. 12 19	. . 2.4
13 M	4 07 16 35	6 37 19 02	2.2 2.1	9 45 22 07	0 42 13 08	2.4 2.5
14 Tu	4 46 17 22	7 22 19 47	2.3 2.0	10 34 22 52	1 28 13 56	2.4 2.6
15 W	5 29 18 13	8 09 20 37	2.3 1.9	11 24 23 41	2 12 14 43	2.4 2.6
16 Th	6 16 19 09	9 00 21 31	2.2 1.7	. .. 12 15	2 57 15 31	2.4 2.5
17 F	7 10 20 10	9 57 22 28	2.1 1.5	0 30 13 08	3 45 16 25	2.2 2.3
18 Sa	8 12 21 15	10 54 23 26	2.0 1.4	1 22 14 04	4 37 17 25	2.0 2.1
19 Su	9 18 22 19	11 53 . ..	1.8 . .	2 18 15 04	5 41 18 34	1.8 1.9
20 M	10 22 23 18	0 26 12 52	1.3 1.7	3 21 16 09	6 52 19 42	1.7 1.9
21 Tu	11 25 . ..	1 33 14 02	1.2 1.6	4 28 17 16	8 02 20 43	1.7 1.9
22 W	0 15 12 27	2 54 15 23	1.3 1.6	5 36 18 16	9 03 21 36	1.8 2.0
23 Th	1 09 13 25	4 02 16 25	1.4 1.7	6 37 19 08	9 56 22 25	1.9 2.0
24 F	1 58 14 18	4 55 17 15	1.6 1.7	7 29 19 53	10 46 23 11	2.0 2.0
25 Sa	2 44 15 08	5 35 17 53	1.7 1.7	8 15 20 34	11 36 23 55	2.0 2.0
26 Su	3 25 15 52	6 09 18 24	1.8 1.7	8 58 21 14	. .. 12 21	. . 2.1
27 M	4 04 16 34	6 37 18 54	1.9 1.6	9 39 21 53	0 37 13 04	2.0 2.1
28 Tu	4 41 17 16	7 09 19 30	1.8 1.5	10 20 22 32	1 18 13 45	2.0 2.1
29 W	5 18 17 59	7 45 20 08	1.8 1.4	11 01 23 12	1 55 14 25	1.9 2.0
30 Th	5 54 18 44	8 25 20 52	1.7 1.2	11 44 23 52	2 33 15 04	1.9 2.0

Day	Slack; Flood Begins	Maximum Flood		Slack; Ebb Begins	Maximum Ebb	
OCTOBER						
	Time	Time	Velocity	Time	Time	Velocity
	h. m.	h. m.	kn.	h. m.	h. m.	kn.
1 F	6 34 19 34	9 11 21 41	1.6 1.1	. .. 12 26	3 10 15 43	1.7 1.9
2 Sa	7 18 20 29	10 00 22 31	1.5 1.0	0 34 13 11	3 48 16 26	1.6 1.7
3 Su	8 12 21 25	10 49 23 22	1.5 1.0	1 20 13 58	4 33 17 19	1.5 1.6
4 M	9 10 22 18	11 40 . ..	1.4 . .	2 10 14 50	5 28 18 20	1.4 1.5
5 Tu	10 11 23 08	0 12 12 32	1.0 1.4	3 04 15 46	6 36 19 22	1.4 1.6
6 W	11 08 23 55	1 05 13 27	1.1 1.4	4 06 16 44	7 39 20 16	1.5 1.7
7 Th	. .. 12 04	2 00 14 24	1.2 1.5	5 09 17 41	8 35 21 04	1.7 1.9
8 F	0 41 12 59	2 58 15 24	1.4 1.6	6 06 18 33	9 25 21 51	1.9 2.0
9 Sa	1 25 13 51	3 52 16 20	1.7 1.8	6 58 19 21	10 14 22 35	2.1 2.2
10 Su	2 08 14 42	4 42 17 10	2.0 1.9	7 46 20 06	11 03 23 22	2.3 2.3
11 M	2 51 15 30	5 28 17 55	2.2 2.0	8 34 20 53	11 54 . ..	2.5 . .
12 Tu	3 34 16 19	6 13 18 39	2.4 2.0	9 22 21 39	0 11 12 45	2.4 2.6
13 W	4 18 17 07	6 58 19 26	2.5 2.0	10 13 22 28	1 00 13 36	2.4 2.7
14 Th	5 03 17 58	7 47 20 16	2.4 1.8	11 04 23 18	1 49 14 26	2.4 2.6
15 F	5 52 18 53	8 38 21 11	2.3 1.7	11 56 . ..	2 37 15 15	2.3 2.5
16 Sa	6 48 19 54	9 35 22 11	2.1 1.6	0 11 12 49	3 27 16 07	2.2 2.3
17 Su	7 52 20 55	10 34 23 12	2.0 1.4	1 07 13 44	4 21 17 05	2.0 2.1
18 M	8 59 21 55	11 33 . ..	1.8 . .	2 05 14 42	5 23 18 10	1.8 1.9
19 Tu	10 06 22 52	0 13 12 33	1.4 1.6	3 06 15 42	6 34 19 16	1.7 1.9
20 W	11 08 23 45	1 18 13 39	1.4 1.5	4 12 16 45	7 43 20 18	1.7 1.9
21 Th	. .. 12 08	2 29 14 54	1.4 1.4	5 19 17 43	8 45 21 09	1.8 1.9
22 F	0 36 13 04	3 33 15 59	1.5 1.4	6 19 18 35	9 36 21 55	1.9 1.9
23 Sa	1 26 13 59	4 26 16 50	1.6 1.5	7 09 19 21	10 23 22 38	1.9 1.9
24 Su	2 10 14 47	5 08 17 31	1.8 1.5	7 53 20 01	11 10 23 21	2.0 1.9
25 M	2 53 15 34	5 41 18 01	1.8 1.5	8 33 20 41	11 55 . ..	2.0 . .
26 Tu	3 32 16 15	6 10 18 31	1.9 1.4	9 13 21 21	0 04 12 39	1.9 2.0
27 W	4 10 16 58	6 41 19 04	1.9 1.4	9 53 22 01	0 45 13 20	1.8 2.0
28 Th	4 46 17 40	7 16 19 42	1.8 1.3	10 34 22 41	1 27 14 00	1.8 2.0
29 F	5 21 18 23	7 56 20 25	1.8 1.2	11 15 23 25	2 05 14 40	1.7 2.0
30 Sa	5 59 19 10	8 40 21 13	1.7 1.1	11 58 . ..	2 43 15 19	1.7 1.9
31 Su	6 42 20 00	9 28 22 04	1.6 1.1	0 08 12 42	3 22 16 01	1.6 1.8

Time meridian 75° W. The hours of the day are numbered consecutively from 0^h (midnight) to 23^h (11 00 p.m.). 12^h is noon. All hours greater than 12 are in the afternoon (p.m.).
On the flood the current sets northward; on the ebb, southward.

Figure 10–14.—Predictions for reference station, table 1.

Table A.—TIDAL CURRENT

Interval between slack and maximum current

Interval between slack and desired time (h. m.)	1 40	2 00	2 20	2 40	3 00	3 20	3 40	4 00	4 20	4 40	5 00	5 20
	f.	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*
0 20	0.3	0.3	0.2	0.2	[illegible]	0.2	0.1	0.1	0.1	0.1	0.1	0.1
0 40	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
1 00	0.8	0.7	[illegible]	[illegible]	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
1 20	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4
1 40	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5
2 00	------	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6
2 20	------	------	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.6
2 40	------	------	------	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7
3 00	------	------	------	------	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.8
3 20	------	------	------	------	------	1.0	1.0	1.0	0.9	0.9	0.9	0.8
3 40	------	------	------	------	------	------	1.0	1.0	1.0	0.9	0.9	0.9
4 00	------	------	------	------	------	------	------	1.0	1.0	1.0	1.0	0.9
4 20	------	------	------	------	------	------	------	------	1.0	1.0	1.0	1.0
4 40	------	------	------	------	------	------	------	------	------	1.0	1.0	1.0
5 00	------	------	------	------	------	------	------	------	------	------	1.0	1.0
5 20	------	------	------	------	------	------	------	------	------	------	------	1.0

Table B.—HYDRAULIC CURRENT

Interval between slack and maximum current

Interval between slack and desired time (h. m.)	1 40	2 00	2 20	2 40	3 00	3 20	3 40	4 00	4 20	4 40	5 00	5 20
	f.	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*	*f.*
0 20	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
0 40	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.4
1 00	0.9	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.5
1 20	1.0	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6
1 40	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.7	0.7	0.7
2 00	------	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.7
2 20	------	------	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.8
2 40	------	------	------	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.8
3 00	------	------	------	------	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9
3 20	------	------	------	------	------	1.0	1.0	1.0	1.0	0.9	0.9	0.9
3 40	------	------	------	------	------	------	1.0	1.0	1.0	1.0	1.0	0.9
4 00	------	------	------	------	------	------	------	1.0	1.0	1.0	1.0	1.0
4 20	------	------	------	------	------	------	------	------	1.0	1.0	1.0	1.0
4 40	------	------	------	------	------	------	------	------	------	1.0	1.0	1.0
5 00	------	------	------	------	------	------	------	------	------	------	1.0	1.0
5 20	------	------	------	------	------	------	------	------	------	------	------	1.0

Use Table A for all places except those listed below for Table B.
Use Table B for Cape Cod Canal, Hell Gate, Chesapeake and Delaware Canal and all stations in Table 2 which are referred to them.

1. From predictions find the time of slack water and the time and velocity of maximum current (flood or ebb), one of which is immediately before and the other after the time for which the velocity is desired.
2. Find the interval of time between the above slack and maximum current, and enter the top of Table A or B with the interval which most nearly agrees with this value.
3. Find the interval of time between the above slack and the time desired, and enter the side of Table A or B with the interval which most nearly agrees with this value.
4. Find, in the table, the factor corresponding to the above two intervals and multiply the maximum velocity by this factor. The result will be the approximate velocity at the time desired.

Figure 10–15.—Velocity of current at any time, table 3.

these two lines in the table intersect, you find the value 0.3. Multiply the velocity of the maximum ebb current (1.87 knots) by this factor and you get 0.561. This is the velocity (drift) of the current at 1500.

What is the direction, or set? Well, you know that the current is still flooding at this time, and flood direction is 20 degrees. Direction of the ebb will be 180° plus 20°, or 200°, the reciprocal of 20 degrees.

HYDROGRAPHIC AND GEODETIC SURVEYING

The principal objective of all hydrographic and geodetic surveying is to secure information concerning the water areas and the adjacent coasts for the compilation of nautical charts and for corrections to existing charts. Hydrography is an applied science that deals with the measurement and description of the physical features of the navigable portions of the earth's surface and adjoining coastal areas, with special reference to their use for navigation purposes. The work combines a variety of activities, including astronomic observations, triangulation, topographic surveys of the coasts, the observation and study of tides and currents, magnetic surveys, oceanography, the measurement of the depths of navigable waters, and the collection of various kinds of data needed in compiling and correcting nautical charts and publications.

The accuracy of a nautical chart depends directly upon the quality of the field surveys. Great care must be taken in evaluating and selecting the data which will appear on the master, or smooth, sheet and the final chart. It is important that there be no omission of any necessary sounding and, on the other hand, that there be no crowding of data which might interfere with the legibility of the chart. The positions of objects on land and sea must be precisely related to the control and to points on other existing charts of the series. Since the development of radar, charts must show all topographical features and navigational aids which would appear on a radar scope.

Preparing the Master Sheet

Because the earth's surface is spherical, any portion of it, no matter how small, that is reproduced on a flat surface will have a distortion error. The smaller the area to be charted, the smaller will be the error. Although most nautical charts are constructed on the Mercator projection, the original field surveys are usually plotted on the polyconic projection. For methods of constructing this projection, see the section on "Construction of the Polyconic Projection" later in this chapter.

Master or smooth sheets for hydrographic and geodetic field surveys are made on special metal-backed or stable plastic-base sheets to minimize distortion caused by extremes of temperature and humidity. The construction of the projection on the sheet should be completed and checked on the same day, if possible.

Plotting the Control

After the projection is made and checked for accuracy, the next step in the preparation of a master sheet consists of plotting the shore control which has been established by previous surveys. Control is necessary in order that land and marine features may be held in their true relationship to each other and in their correct geographic position on the surface of the earth. The control stations must be plotted with great precision because any inaccuracy will result in errors in the positions of the soundings. This is especially important because the error increases with the distance from the control station. Figure 10–16 illustrates a triangulation diagram made by Navy hydrographers to serve as control for a particular hydrographic survey. The area to be surveyed can be seen in figure 10–17.

There are several methods of plotting the shore control on the master sheet, depending upon the form in which the data is available. Triangulation stations are usually plotted by the *dms.* (meridional differences) and

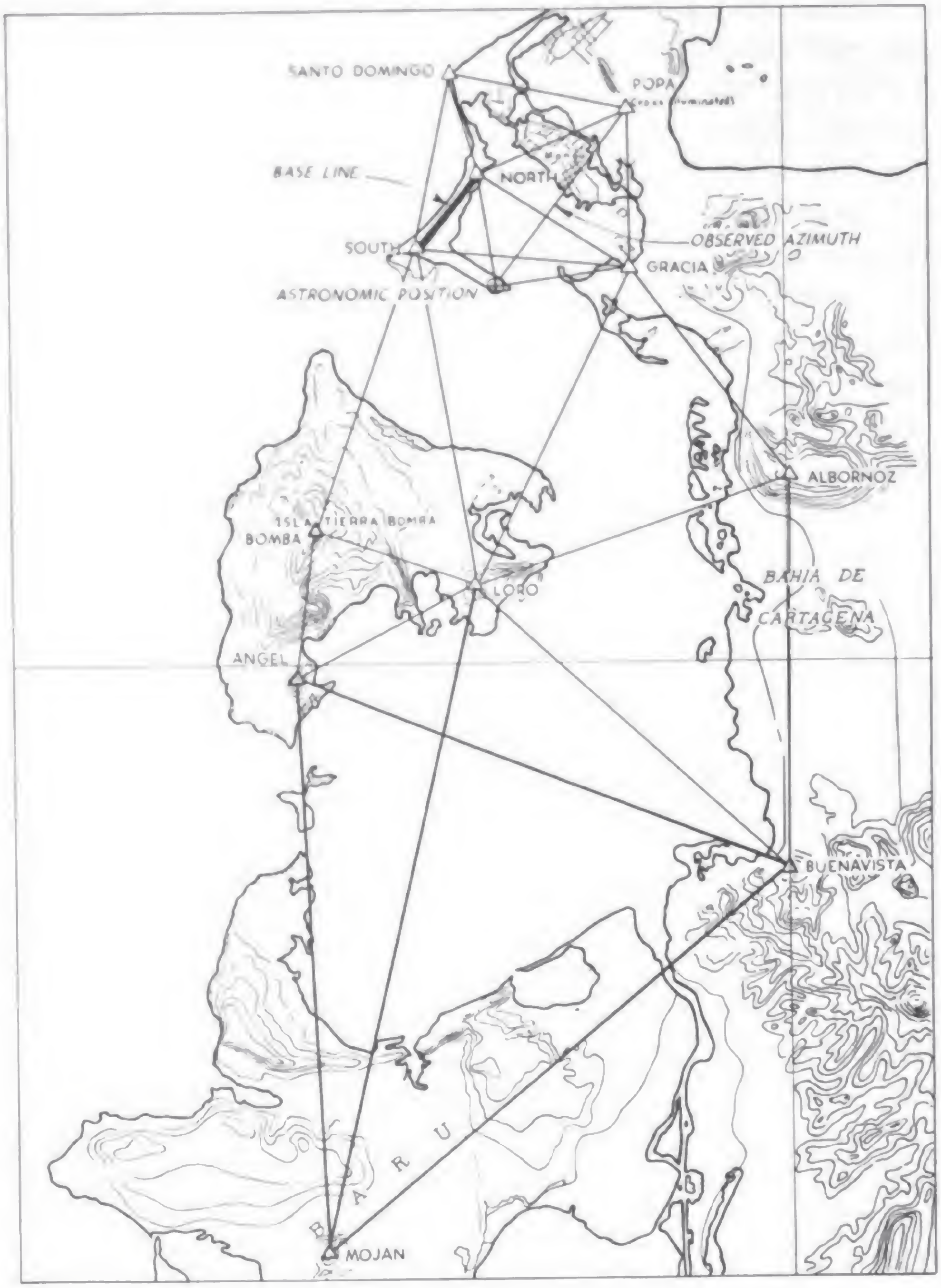


Figure 10–16.—Triangulation diagram.

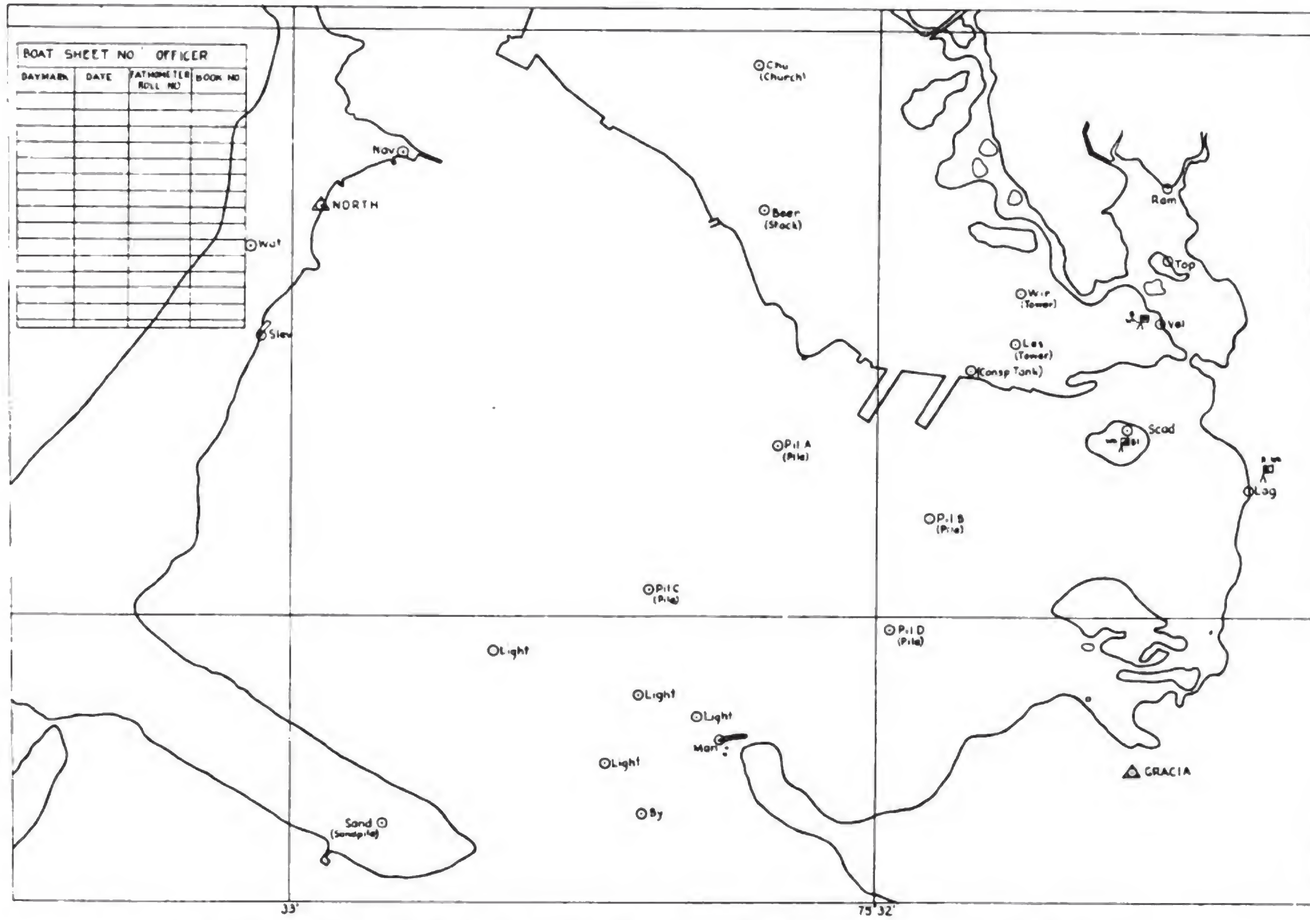


Figure 10–17.—Master sheet showing the projection, control, and topography.

the *dps.* (parallel differences) method after their respective geodetic positions have been completed.

PLOTTING BY DMS. AND DPS.—The latitude and longitude in degrees, minutes, and seconds are given for each station, as well as the distances and azimuths between stations. The equivalents in meters of the seconds of latitude and longitude are also given for stations along the coast and these are known as the *dms.* (meridional differences) and *dps.* (parallel differences), respectively, of the stations. Thus, if the position of a station is given as latitude 54°44′34″.189 N. (1,057.2 meters), longitude 130° 56′42″.362 W. (756.5 meters), its *dm.* is 1,057.2 meters north of the 44-minute parallel, and its *dp.* is 756.5 meters west of the 56-minute meridian.

To plot a triangulation station, first identify the quadrilateral on the projection within which the station falls. With a pair of dividers and a metric scale, plot its *dm.* near each meridian line and mark with a fine prick point. Connect the two points thus plotted with a fine pencil line, using a chisel-edge 6H pencil. Plot the *dp.* of the station along this line and mark with a fine prick point. This will be the position of the station provided there is no distortion in the paper.

As a check of the plotting, and to compensate for any possible distortion, the station must also be plotted from the north parallel and the west meridian of the quadrilateral. These distances are the back *dm.* and back *dp.* for the station, and if not already available, they may be obtained by subtracting the *dm.* and *dp.* values from the value of 1 minute of latitude and longitude, respectively, as given in the polyconic projection tables for the latitude of the station. If the sheet contains an appreciable amount of distortion, the plotted distances will result in two pairs of points, each pair closely adjacent. The true position of the station will be at a distance from the points proportional to their respective distances from the projection lines. (See fig. 10–18.)

The position of the station should be marked with

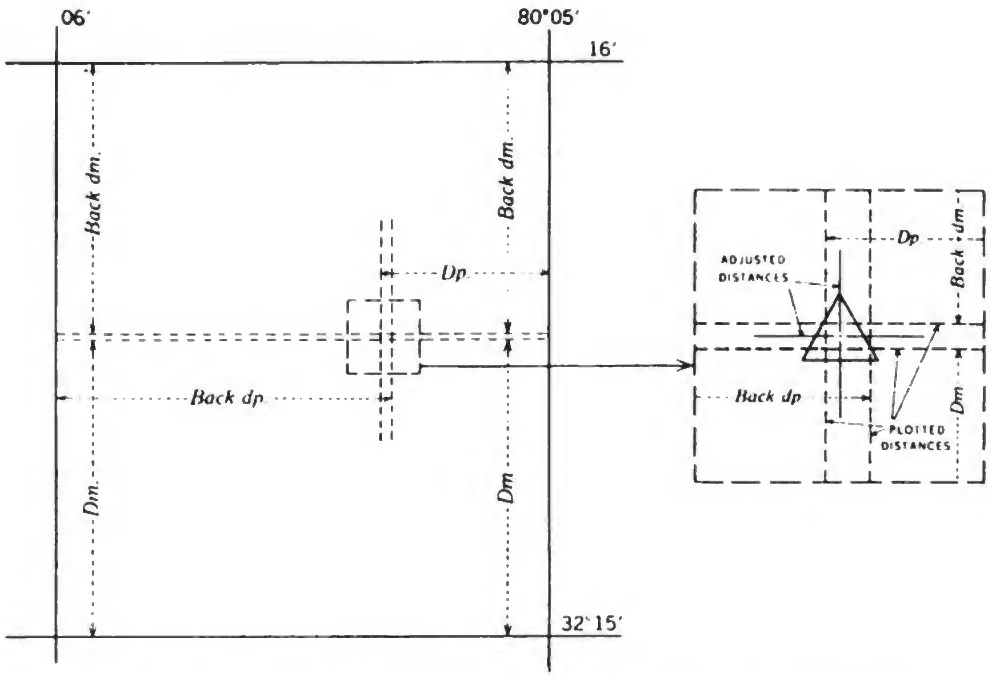


Figure 10–18.—Control station plotted by *dm.* and *dp.* on a distorted sheet.

a fine prick point and identified temporarily by a small circle and the name of the station, both in pencil.

When you plot by *dms.* and *dps.*, do not use the intersections of meridians and parallels to plot from, but use points on the parallels or meridians slightly offset from the intersections. Always use a magnifying glass for setting the dividers on line and for selecting the final position of the station. The beam compass should be used if the distances are too long to plot accurately with dividers.

On recently constructed master sheets in which there is a minimum of distortion, triangulation stations should always be plotted by the *dms.* and *dps.* method. The plottings may be checked with the latitude and longitude scales. Geographic positions may also be plotted with latitude and longitude scales. These are similar in appearance to a triangular engineer scale, each containing one scale for the plotting of latitude and five scales for the plotting of longitude at various latitudes. With these scales a geographic position is plotted by minutes and seconds directly.

PLOTTING BY TRANSFER.—The stations located by topography are usually placed on the master sheet by transfer from the topographic sheet. Ordinarily the topographic survey has immediately preceded a hydrographic survey. In such cases, the scales are identical and, if there is no distortion in either sheet, the fastest method of transferring the positions of the signals to the master sheet is by tracing paper. Tracing cloth should not be used for this purpose because it is subject to larger dimensional changes than the paper.

Fasten the tracing paper securely over the topographic sheet and use a needle, or other fine point to prick the exact positions of the topographic stations and the adjacent projection intersections through the paper. The shoreline and topography are usually transferred at the same time. Identify the stations temporarily by symbols in pencil. Then place the tracing paper on the master sheet with the corresponding projection-line intersections exactly superimposed, and prick the positions of the topographic stations through the holes in the tracing paper into the smooth sheet. Then mark them temporarily in pencil.

If there is distortion in one or both of the sheets, the projection intersections will not all coincide. In this case, the tracing paper must be adjusted for each quadrilateral so that the difference between the two projections is proportioned for each station plotted. Sometimes, the tracing has to be shifted several times, as where stations are located in different parts of the quadrilateral. Even if there is no apparent difference between the two projections the coincidence of the adjacent intersections should be verified before the stations are pricked through.

Control station may be transferred from one sheet to another by proportional dividers, but this method should be used only where the transfer is from a comparatively large-scale survey to a comparatively small-scale one.

PLOTTING BY CUTS.—Cuts are sextant angles, usually taken from a survey ship, between an object whose posi-

tion is known and an object whose position is to be determined. The position of the observer is located by two sextant angles. Two or more such cuts taken from different positions determine the position of the unknown object. Cuts may also be taken from previously located shore stations.

To plot a control station from sextant cuts, first carefully plot the position of the observer, if he is not located at a previously determined station. To do this, use a metal protractor with an adjustment that has been previously checked. Next, set the third angle, or cut, on the protractor, place the center directly over the observer's position with one arm passing through the known station, and plot the angle to the new station by a short line drawn along the edge of the protractor arm with a hard chisel-edged pencil. Temporarily identify the name of the new station in pencil. Plot all other cuts to this same station in a similar manner from the respective locations from which they are taken.

If the observing has been carefully done and, based on control, precisely located, and the sheet is free from distortion, all the cuts should intersect at one point, which is the location of the station. It rarely happens that this is the case, and a position must be adopted which will most nearly fall on all of the plotted cuts, taking into consideration their respective probable accuracies.

Control stations are sometimes located by three-point fixes at the station. In such cases, their positions may be plotted on the master sheet with the three-arm protractor verifying the plotting with the check angle, if taken.

PLOTTING THE FLOATING CONTROL.—The floating control which may be used to control a hydrographic survey usually consists of survey buoys or sono-radio buoys, and occasionally small marker buoys. There are various methods of determining the positions of such buoys depending upon the availability of shore signals, the distance offshore, the character of the area surveyed, etc.

The positions of the floating control are ordinarily

known prior to the construction of the master sheet, since they must be known in order to execute the field work. There are two general methods of obtaining these positions, (a) by computation and (b) by graphic plotting on an aluminum sheet. In both methods the geographic positions of the buoys, and consequently their *dms.* and *dps.* are obtained. Thus, the positions of the buoys are plotted on the smooth sheet in the same manner that shore stations are plotted by *dms.* and *dps.*

PLOTTING THE TOPOGRAPHIC DETAIL.—Figure 10–17 shows the master sheet after the topography has been transferred to the projection. Topographic detail must never obscure the centers of control stations. Note also that the shoreline is usually the mean high water line except in marsh or mangrove areas, in which case it represents the edge of the marsh. A master sheet contains on a single sheet all the information essential to the intelligent planning and completion of the work.

Preparing the Boat Sheet for Hydrography

The boat sheet is the worksheet used by the hydrographic party in the field for plotting the details of a hydrographic survey as it progresses. Each sounding party is given a boat sheet which indicates its specific area of operations. To make an overlay for use as a boat sheet, place a sheet of transparent plastic over the master or smooth sheet and prick through control stations and intersections of parallels and meridians. Transfer these to a sheet of mounted paper and add the shoreline. Several sheets may be required depending upon the size of the area to be sounded.

A boat sheet for an inshore hydrographic survey should contain the following details as available: the high-water line, the low-water line, the approximate limits of shoal areas, rocks (bare, awash, and sunken), aids to navigation, and any suspected dangers which the topographer may have noted but may not have been able to verify. All control stations whose positions are known at

the start of the survey should be plotted on or transferred to the boat sheet. All data from prior surveys, such as dangers to navigation, soundings at junctions with adjacent surveys, and depth curves, should be transferred to the boat sheet in colored ink, preferably red.

In addition to known shoals and dangers, plot any reported menaces to navigation, which may not have been charted as yet, so that their positions may be accurately determined or disproved. Sometimes a compass rose and a graphic speed scale are also included on the boat sheet. Boat sheets for uncharted areas usually contain only the graticule, shoreline, and control points. The shoreline represents a rough compilation from uncontrolled photographs, when available.

After the boat sheet is prepared, a system of sounding guidelines is selected to enable the sounding party to develop the area in a systematic and economic manner. Three systems of sounding guidelines are used: parallel lines, radiating lines, and a grid. Each survey area or part of a survey area may require a different system. For example, in the boat sheet shown in figure 10–19, the system of parallel lines is used. Both the system and the spacing of sounding lines must furnish a realistic representation of the sea bottom and the submarine relief.

Figure 10–20 shows all the systems of sounding guidelines in use. The solid lines represent depth curves; the broken lines represent appropriate systems for the various conditions encountered. Note that for the development of steep ridges or valleys, the system of sounding guidelines crosses the depth curves at an angle of approximately 45 degrees.

Returning to our example of a boat control sheet, note in figure 10–19 that, in addition to the system of parallel lines, broken lines are shown on which stations are numbered 90a, 91, 92, and so forth. These stations represent the exact location of the survey boat when soundings were made. The small letter with a position number is the day mark; "a" being the first day, "b" the second,

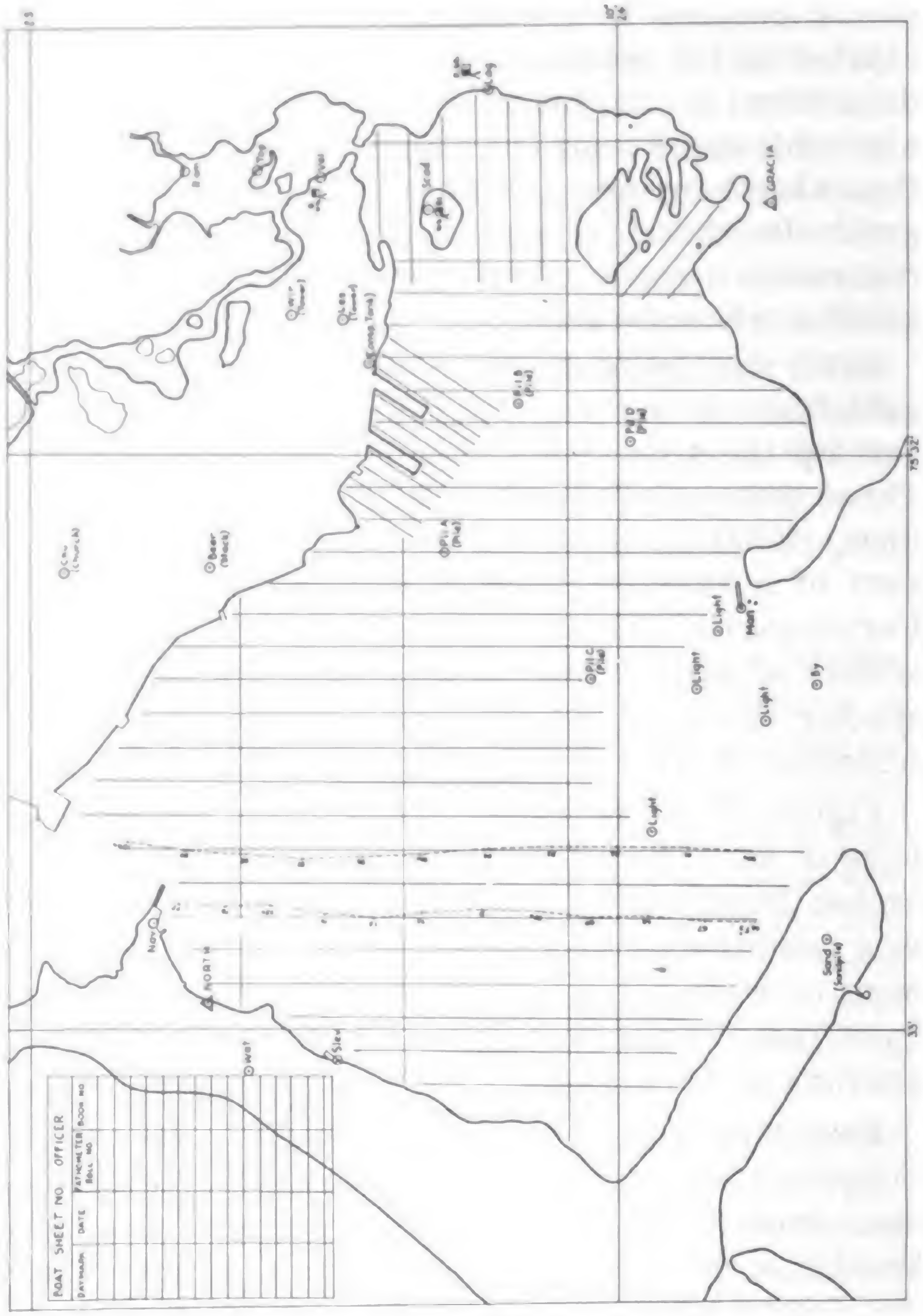


Figure 10–19.—The boat sheet showing the projection, control, and sounding guidelines.

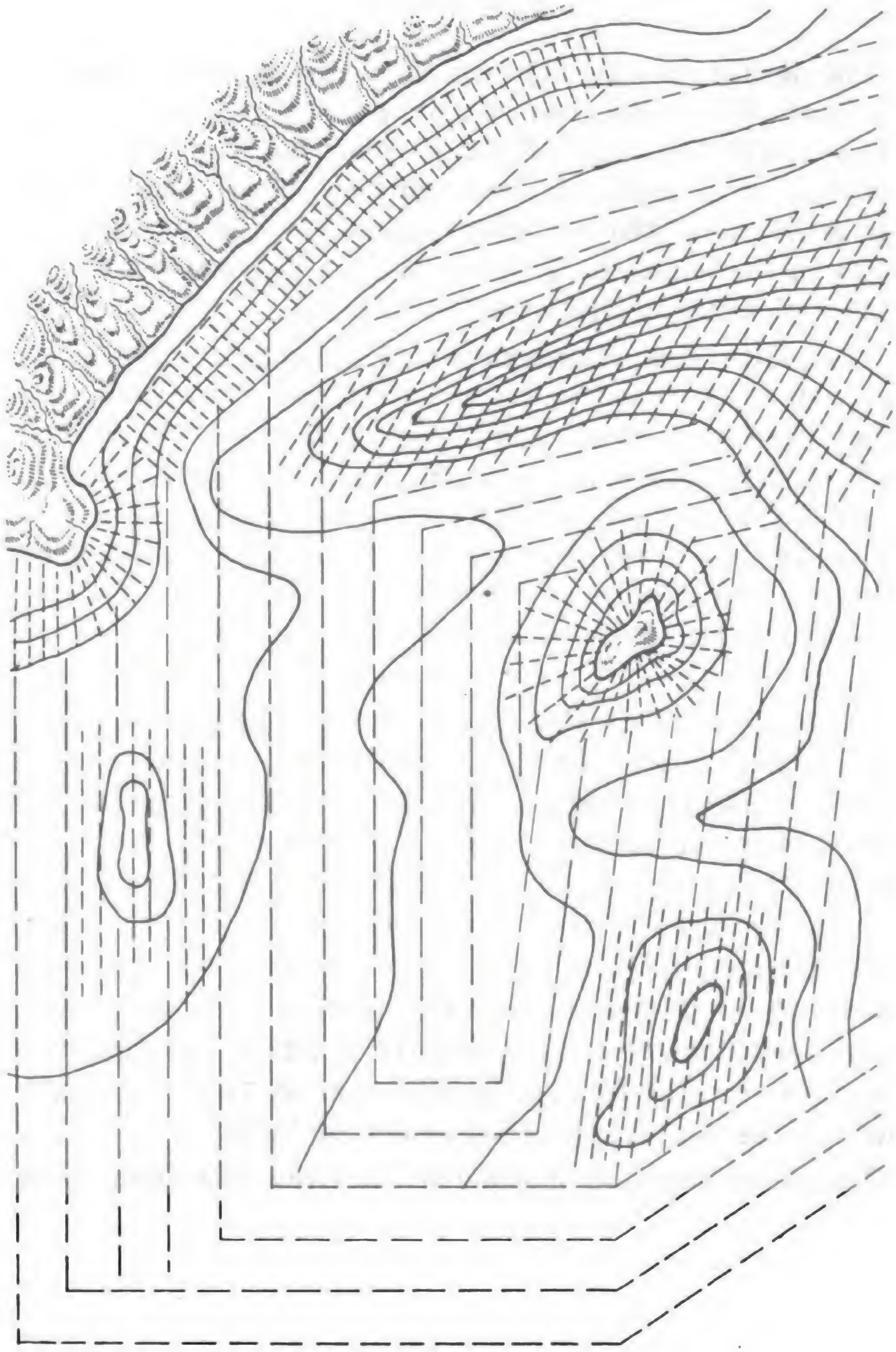


Figure 10–20.—Representative systems of sounding guidelines.

etc. It is of interest to observe that the survey vessel cannot always be exactly on the parallel.

Duties of the Plotter

The plotter on a survey ship or sounding boat is usually the boat officer. Because you as a DM1 or C may sometimes assist the boat officer in plotting, you should be familiar with some of these duties. During the sounding operations, the recorder enters the observations or notes in the sounding journal, and at the same time the plotter plots the positions on the boat sheet.

The plotter also makes sure that the speed of the vessel is constant, selects the signals for fixes, plots fixes, and determines how many yards the boat is off the line at each position, or what change of course is necessary to bring the boat back to line. With the naming of a new fix at the next position, he calls out the approximate bearings and angles to help the observers find the signals on the horizon, if and when the signals are hard to pick up.

When he believes that the observed angles are incorrect because they fail to plot properly, he calls for a second reading. If this occurs, the recorder corrects the angles without erasure and makes the notation READ AGAIN. The plotter also calls out corrections of any errors in naming signals to the recorder. He plots, in pencil, sufficient soundings to keep track of the distances from shore where fathom lines are crossed, and especially shoal soundings that may require further investigation. He gives warning by calling out SLOW ON THE NEXT POSITION as the boat approaches shoals or land.

The most common method of plotting positions is by means of the three-arm protractor, because soundings are usually located by three-point fixes. When the three-arm protractor is not available, soundings can be located with a piece of tracing paper. Figure 10–21 shows the soundings plotted on the boat sheet.

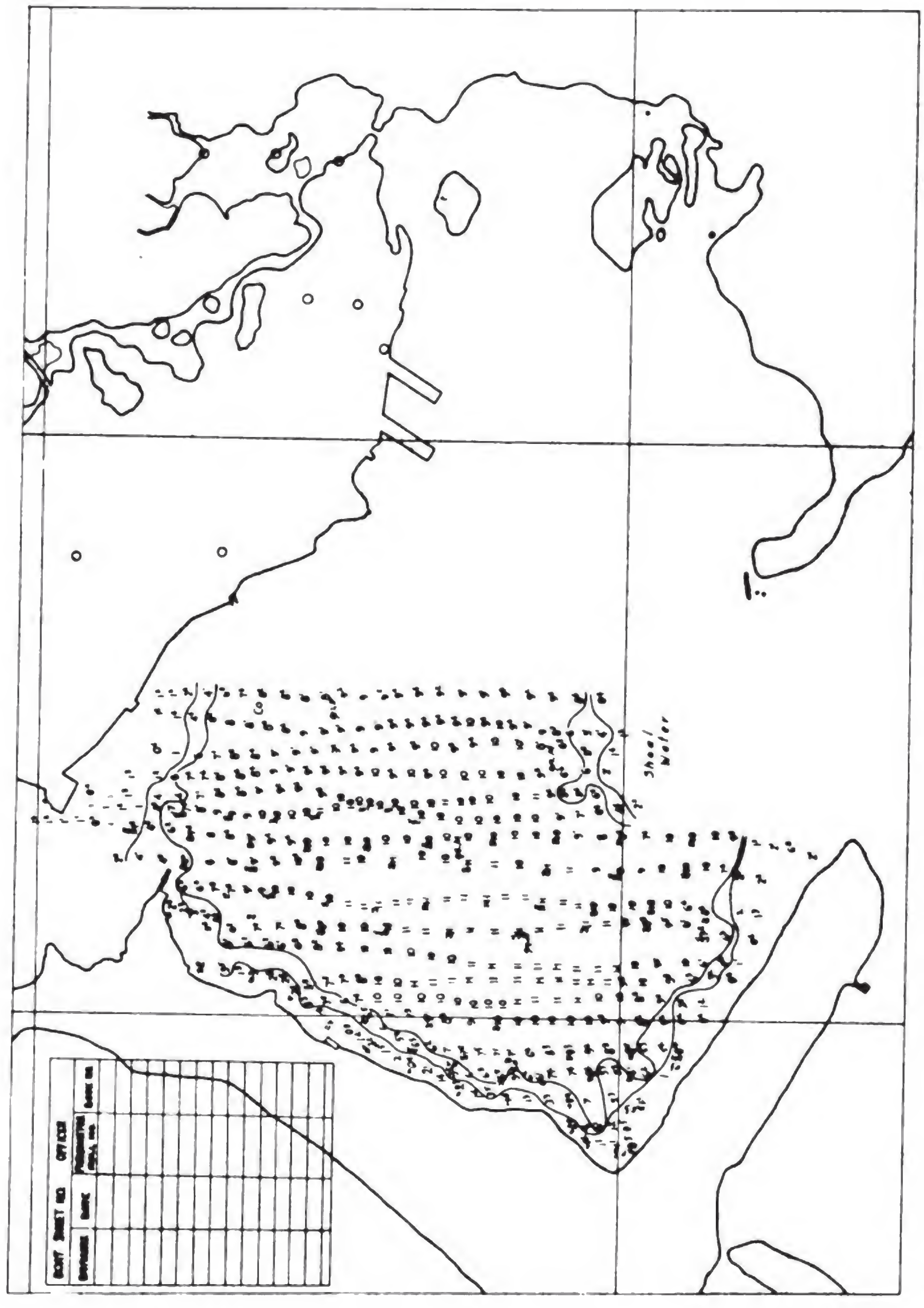


Figure 10–21.—Soundings plotted on the boat sheet.

Completing the Master Sheet

The master sheet is a graphic record of a hydrographic survey. It is, in effect, a map of the surveyed area. The method followed in plotting the positions on the master sheet is essentially the same as that used in plotting positions on the boat sheet, except that the work on the master sheet is performed with greater precision. The most experienced surveyors or draftsmen perform this work under the close supervision of an officer.

With a little experience, the plotter soon learns to detect where there is some deficiency in the recorded data. For best results, the plotter should be thoroughly familiar with the methods by which the field work was done so that he will be able to visualize the progress of the boat during the work. The plotter must make constant reference to the notes in the Remarks column of the sounding journal and to the boat sheet as a check on the accuracy of the smooth plotting.

To avoid soiling the master sheet during the plotting, you should keep it completely covered except for the small area you are actually working on. Begin with position No. 1 of the day's work and plot the boat positions in the order in which they were taken in the field. Space the soundings between fixes in strict accordance with the specifications. Take into consideration any changes in the speed of the boat between positions. Regardless of the spacing, the shoalest soundings between fixes are always indicated. Where soundings fall close to control stations in the water area, take care that the soundings do not obscure the station points.

Because the echo method is normally used, you will have considerably more soundings than can be conveniently shown on the master sheet. You must, therefore, make a careful selection under the direction of the boat officer, to include all those soundings which are essential to showing the depth surveys accurately.

Depth curves are similar to contours on land. They show the general configuration of the bottom emphasiz-

Figure 10-22.—Completed master sheet.

ing important navigational features such as shoals and channels. Additional detail is often included on the master sheet in the form of explanatory notes. These include data concerning rocks, reefs, ledges, silted areas, landmarks, navigational aids, overhead clearances, sailing lines, tide rips, marine vegetation, wrecks, obstructions, and the like. (See fig. 10–22.)

POLYCONIC PROJECTION

The polyconic projection is the development of an area by means of successive cones tangent to the surface at successive parallels, as shown in figure 10–23. The central meridian of any polyconic projection is a straight line. All other meridians and all parallels are curved lines, except for the special case of the Equator which is a straight line.

The parallels are arcs of nonconcentric circles with radii of decreasing length as the latitude increases, but whose centers lie in the extension of the central meridian. The curved meridians are concave toward the central meridian in increasing amounts as the distance from the central meridian increases. Practically, in the large scales usual in hydrographic surveying, the meridians may be considered straight lines within the limits imposed by graphic methods of construction. The longitude scale is everywhere correct, but the latitude scale is strictly correct only on the central meridian.

Verification of Scales and Straightedges

Before beginning the construction of the projection, you should verify the correctness of the meter bar and meter scales and the straightedges, unless definite information of their correctness is at hand. The best test that can be applied in the field as to the accuracy of the meter scales is by comparison with a meter bar known to be correct.

To test a straightedge, prick two fine dots on a thick

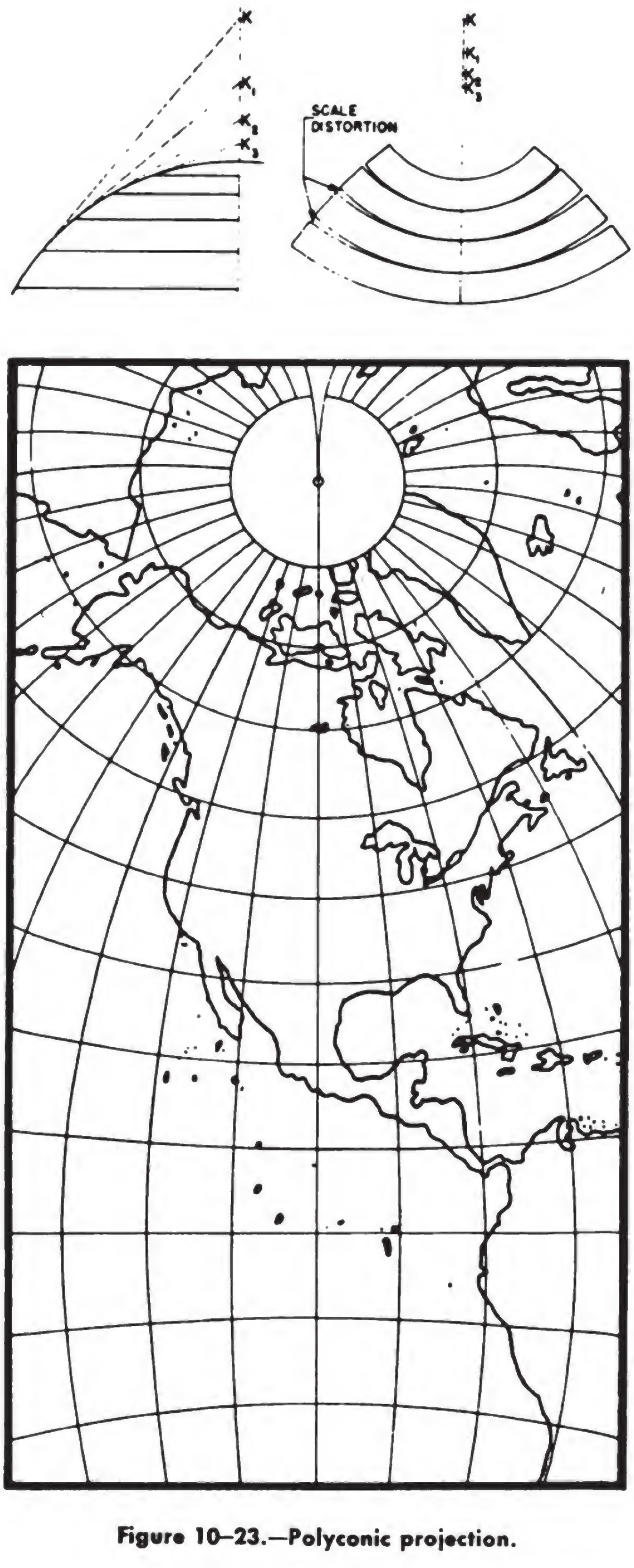


Figure 10–23.—Polyconic projection.

sheet of paper at a distance apart slightly less than the length of the straightedge. Center the edge of the straightedge through these two dots, and draw a fine pencil line carefully along it with a chisel-edged pencil. Hold the pencil firmly against the edge at a constant angle with the paper. Then turn the straightedge over end for end and again center it through the pricked points. If the edge coincides with the pencil line throughout its length, it is straight, unless, of course, it happens to have a symmetrical reverse curve. You will find a magnifying glass helpful when you make this test.

Construction of a Polyconic Projection

The construction of a polyconic projection is a comparatively simple problem, but extreme accuracy and care are necessary. A meter bar, beam compass, straightedge, dividers, and a quarter-meter scale are needed. All the elements are to be found in the U. S. Coast and Geodetic Survey Special Publication No. 5, *Tables for a Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridians and Parallels.* The area to be covered, the orientation of the sheet, and the scale are found in the specifications for the project. The interval between the projection lines to be drawn depends on the scale.

First, locate the intersection of the most central meridian and parallel which are to be shown. The accuracy with which this should be done depends on how near the edge of the sheet the work will extend. If extreme accuracy is required, it is generally necessary to lay off carefully the limits of the sheet on a published chart of the area, thus locating the central intersection and the orientation. In some cases, even preliminary mathematical computations are necessary to ensure the inclusion of the required control points, as, for example, where they fall dangerously close to opposite edges of the sheet.

It is a good idea to make a rough sketch of the projection on a sheet of paper first, noting on it all the distances (as taken from the projection tables) to be plotted with

the meter bar and beam compass. These distances should, of course, be reduced for use directly on the meter bar. For instance, if the projection is to be 1:40,000 and the scale of the meter bar is 1:20,000, all distances taken from the tables must be halved.

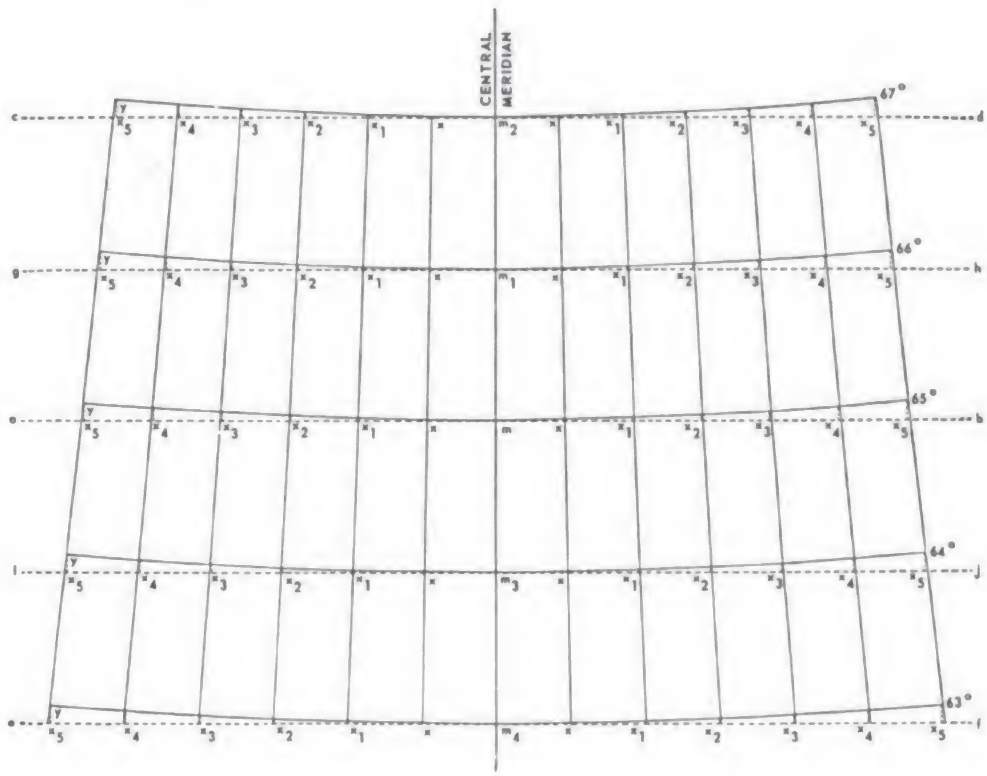


Figure 10–24.—Construction for the polyconic projection.

Now look at figure 10–24. When you have located the area to be covered by the projection and determined the scale and the interval of the projection lines, draw a straight line for a central meridian. Then draw a construction line, shown as *ab* in the figure, which is perpendicular to the central meridian. These should be as central to the sheet as the selected interval of latitude and longitude will permit.

On the central meridian and from its intersection with the construction line *ab*, lay off the intervals of latitude, north and south, using the meter bar and compass. These are shown as the distances mm^1, mm^2, mm^3, and mm^4, and

are taken from the table headed "Meridional Arc" under "Continuous sums of minutes" in the Coast and Geodetic Survey Special Publication No. 5. Since the lengths of the arcs of meridians and parallels change when the latitude changes, ALL DISTANCES must be taken from the table opposite the latitude of the point in use.

Through the points m^2, m^4, m^1, and m^3 respectively, draw the straight construction lines *cd*, *ef*, *gh*, and *ij* parallel to *ab*. Then lay off the distances mx, mx^1, mx^2, mx^3, mx^4, and mx^5 along these construction lines from the central meridian. For projections at scales of 1:40,000 or larger, these distances for each parallel are taken from the table headed "Arcs of the parallel to meters"; for scales smaller than 1:40,000, they must be taken from the values of X under the table headed "Coordinates of curvature" in the Coast and Geodetic Special Publication No. 5, interpolating for latitudes and longitudes intermediate between those given in the tables. It is especially important that these distances be laid off from the central parallel and the central meridian. The successive points m^1, m^2, etc., and x, x^1, x^2, etc., must never be laid off from one another.

Next, enter the projection table headed "Coordinates of curvature" in Special Publication No 5 and find the y values corresponding to the respective x points. These values are laid off parallel to the central meridian, north of the construction lines if the projection is north of the Equator. These are usually short distances and difficult to plot. Best results can be attained by plotting an arbitrary distance, such as 100 or 200 meters on a 1:20,000 scale, south of the x-points, and then plotting the arbitrary distance plus the y values north from the arbitrary points.

Y values for latitudes intermediate between those given in the tables can be obtained by linear interpolation, but for longitudes intermediate between the tabular values, the following relationship should be used:

The ratio of any two successive ordinates of curvature

in meters, equals the ratio of the squares of the corresponding absciss as, expressed in minutes or degrees.

This approximation is close enough under most conditions.

Each of the points plotted north of its respective x-point represents the intersection of a meridian and a parallel. Curved lines drawn through these points represent the meridians and parallels. Because it is difficult, in practice, to draw a curve of very large radius, the intersection points must be frequent enough so that the curved meridians and parallels can be drawn as a series of chords which will approximate the true curves. The projection must be left in pencil until verified and the control has been plotted. Finally, the projection should be checked by measuring the intercepted distances between the adjacent meridians and parallels.

On projections of scales 1:10,000 or larger, it is generally sufficient to apply the y-coordinates at the extreme meridians only, joining these points and the corresponding points on the central meridian with straight lines. The parallels so drawn are then subdivided equally for determinlng the intermediate meridians.

The construction of a polyconic projection is fully explained in U. S. Coast and Geodetic Survey Special Publication No. 5, and again in Special Publication No. 68, *Elements of Map Projection.* The latter publication also gives the formula from which the errors of scale and area of any polyconic projection may be determined.

Continuous Construction

The construction of a projection must be continuous; that is, it must not be begun and then laid aside to be resumed at a later date. It should be completed and checked on the same day, if possible. Construction on days of excessive humidity or excessive dryness should be avoided. When possible, the projection should be made at a time of day and during a period of weather when the atmospheric conditions are stable and nearly average for the

conditions under which the smooth sheet is to be used. It is important during construction that the projection not be exposed to the direct rays of the sun.

Verification of the Projection

All details of the construction of the projection must be checked. This must be done while the projection is still in pencil, and must consist of a verification of the values taken from the polyconic projection tables and a complete check by measurement of the construction of the projection. Finally, corresponding diagonal distances should be compared with one another.

It is to be noted that the polyconic projection is symmetrical with respect to the central meridian. Therefore, the diagonal distance between any two intersections on one side of the central meridian is equal to the diagonal distance between two corresponding intersections on the opposite side of the central meridian. A good construction check is a comparison of the long diagonal distance from the northeast to the southwest corner through the construction center with the corresponding distance from the northwest to the southeast corner.

The verification must be made the same day that the projection is constructed and, if practicable, immediately following the construction.

CONSTRUCTION OF A MERCATOR PROJECTION

On the Mercator projection, meridians of longitude and parallels of latitude are straight lines intersecting at right angles. The distances between meridians are equal throughout the chart, but distances between parallels increase progressively from the Equator toward the poles. Since on the globe, the meridians approach each other until they meet at the poles, the fact that the distances between meridians on the Mercator projection are kept the same means that the distances between parallels must be increased in order to keep the scale in proportion to the scale on the earth.

Tables

The tables in appendix V are taken from U. S. Coast and Geodetic Survey Special Publication No. 68, *Elements of Map Projection*, and were originally published in *Traite d' Hydrographie* by A. Germain, 1882, Table XIII. These tables are to three decimal places, which gives sufficient accuracy for all practical purposes.

The outer column of minutes give the notation of minutes of latitude from the Equator to 80 degrees. The column of meridional distances gives the total distance of any parallel of latitude from the Equator in terms of a minute or unit of longitude on the Equator. The column of differences gives the value of 1 minute of latitude in terms of a minute or unit of longitude on the Equator. Thus, the length of any minute of latitude on the map is obtained by multiplying the length of a minute of longitude by the value given in the column of differences between adjacent minutes.

The first important step in the use of the Mercator table is to note the fact that a minute of longitude on the Equator is the unit of measurement and is used as an expression for the ratio of any one minute of latitude to any other. The method of construction is simple, but, on account of different types of scales employed by different chart-producing establishments, it is desirable to present two methods: (1) the diagonal metric scale method and (2) the method similar to that given in Bowditch's *American Practical Navigator*.

Diagonal Metric Scale Method

The diagonal metric scale method of constructing a Mercator projection is used in the U. S. Coast and Geodetic Survey.

Draw a straight line for a central meridian and a construction line perpendicular to it. Each of these should be as central to the sheet as the selected interval of latitude and longitude will permit. To ensure greater accu-

racy on large sheets, the longer line of the two should be drawn first, and the shorter line erected perpendicular to it.

For example, suppose a Mercator projection is required covering the area of Portsmouth, N. H., and Biddeford, Maine, and extending from latitude 43°00′ to 43°30′ and from longitude 70°00′ to 71°00′. The scale on the middle parallel is to be 1:400,000, and the projection interval 5 minutes. (See fig. 10–25.)

Figure 10–25.—Mercator projection—construction plate.

Since the middle latitude is 43°15′, we take as the unit of measurement the true value of a minute of longitude for this latitude. This is given in U. S. Coast and Geodetic Survey Special Publication No. 5, *Tables for Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridians and Parallels.* (The general spherical coordinates are not given in the Germain tables.) Entering the proper column on page 96, you will find that the length of a minute of longitude at latitude 43°15′ is 1353.5 meters.

Since metric diagonal scales of 1:400,000 are neither available nor convenient, a scale of 1:10,000 is ordinarily used, and since this latter scale is 40 times the former, the length of a unit of measurement on it will be one-fortieth of 1353.5, or 33.84.

Lines representing 5-minute intervals of longitude can now be drawn on either side of the central meridian and parallel at intervals of 5×33.84, or 169.2, apart on the 1:10,000 scale. In practice, it is advisable to determine the outer meridians first, 30 minutes of longitude being represented by 6×169.2, or 1015.2.

The distance between 43°00′, the bottom parallel of the chart, and the next 5-minute parallel, or 43°05′, can be ascertained from the Mercator tables by taking the difference between the meridional distances opposite these parallels and multiplying this difference by the unit of measurement, which is 33.84.

Thus,

Latitude	*Meridional Distance*
43°05′	2853.987
43°00′	2847.171
	6.816

Then, $6.816 \times 33.84 = 230.6$, which is the spacing from the bottom parallel to 43°05′.

The spacing of the other 5-minute intervals obtained in the same way are as follows:

Latitude	*Spacings*
43°30′	232.3
43°25′	232.0
43°20′	231.6
43°15′	231.3
43°10′	231.0
43°05′	230.6
43°00′	
Total height of chart	1388.8

From the central parallel, 43°15′, the other parallels can now be stepped off and drawn as straight lines and the projection completed. Then draw the outer neat lines of the chart at a convenient distance outside of the inner neat lines and extend to them the meridians and parallels already constructed. Between the inner and outer neat lines of the chart subdivide the degrees of latitude and longitude as minutely as the scale of the chart will permit. The subdivisions of the degrees of longitude are found by dividing the degrees into equal parts. The subdivisions of the degrees of latitude are accurately found in the same manner as the 5-minute intervals of latitude already described, though it will generally be sufficiently exact on large-scale charts to make even subdivisions of these intervals of latitude, as in the case of the longitude.

In northern latitudes, where the meridional increments are quite noticeable, care should be taken to compute latitude intervals or subdivisions with sufficient closeness, so that their distances apart will increase progressively.

The subdivisions along the eastern, as well as those along the western neat line, will serve for measuring or estimating terrestrial distances. Distances between points bearing north and south of each other may be ascertained by referring them to the subdivisions between their latitudes.

Distances represented by lines (rhumb or loxodromic) at an angle to the meridians may be measured by taking between the dividers a small number of the subdivisions near the middle latitude of the line to be measured, and stepping them off on that line. If, for instance, the terrestrial length of a line running at an angle to the meridians, between the parallels of latitude 24°00′ and 29°00′ are required, the distance shown on the neat space between 26°15′ and 26°45′ may be taken between the dividers and stepped off on that line. An oblique line of considerable length may well be divided into parts and each part referred to its middle latitude for a unit of measurement.

Method Similar to That Given in Bowditch's American Practical Navigator

If the chart includes the Equator, the values found in the tables will serve directly as factors for any properly divided diagonal scale of yards, feet, meters, or miles. These factors should be reduced proportionally to the scale adopted for the chart.

If the chart does not include the Equator then the parallels of latitude should be referred to a PRINCIPAL PARALLEL, preferably the central or the lowest parallel to be drawn on the chart. The distance of any other parallel of latitude from the principal parallel is the difference of the values of the two taken from the tables and reduced to the scale of the chart.

If, for example, you are required to construct a chart on a scale of one-fourth of an inch to 5 minutes of arc on the Equator, the minute or unit of measurement will be $\frac{1}{5}$ of $\frac{1}{4}$ inch, or $\frac{1}{20}$ of an inch, and 10 minutes of longitude on the Equator (or 10 meridional parts) will be represented by $\frac{10}{20}$ or 0.5 inch. Likewise 10 minutes of latitude north or south of the Equator will be represented by $\frac{1}{20} \times 9.932$ or 0.4966 inch. The value 9.932 is the difference between the MERIDIONAL DISTANCES as given opposite latitude $0°00'$ and $0°10'$.

If the chart does not include the Equator, and if the middle parallel is latitude 40°, and the scale of this parallel is to be one-fourth of an inch to 5 minutes, then the measurement for 10 minutes on this parallel will be the same as before, but the measurement of the interval between $40°\ 00'$ and $40°\ 10'$ will be $\frac{1}{20} \times 13.018$, or 0.6509 inch. The value 13.018 is the difference of the meridional distances as given opposite these latitudes, or the difference between 2620.701 and 2607.683. (It may often be expedient to construct a diagonal scale of inches on the drawing to facilitate the construction of a projection on the required scale.)

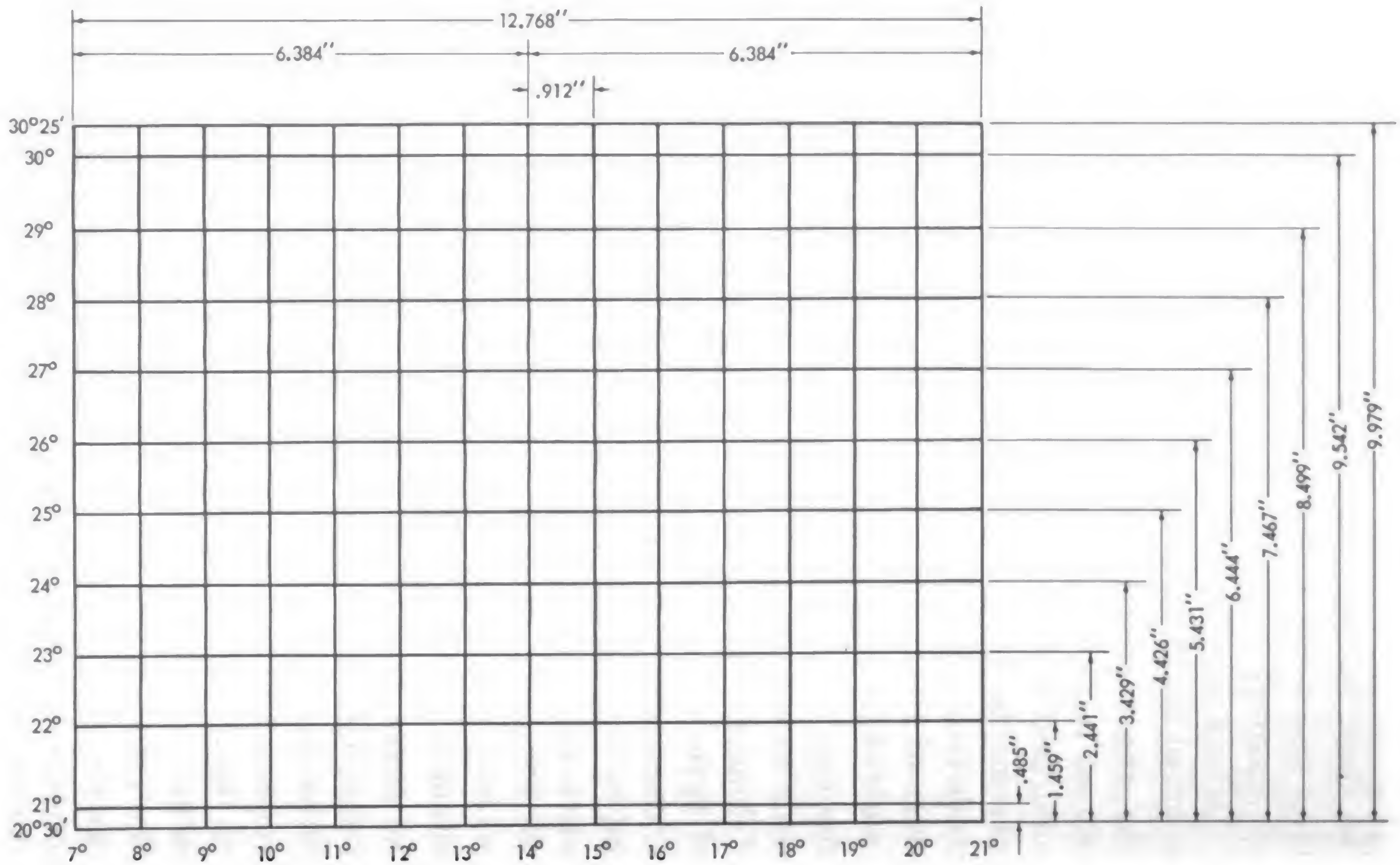


Figure 10–26.—Mercator projection constructed according to method similar to that in Bowditch's *American Practical Navigator*.

Sometimes it is desirable to adapt the scale of a chart to a certain allotment of paper. For example, let a projection be required for a chart of 14° extent in longitude between the parallels of latitude 20° 30′ and 30° 25′, and let the space allowable on the paper between these parallels be 10 inches. (Note that the area represented includes 499,800 square miles. It is highly improbable that you would ever have occasion to do a projection covering this large an area. Consider this only an example.)

First, draw in the center of the sheet a straight line for the central meridian of the chart. Construct carefully two lines perpendicular to the central meridian and 10 inches apart, one near the lower border of the sheet for parallel of latitude 20°30′ and an upper one for parallel of latitude 30°25′.

Entering the tables in the column headed Meridional Distance, you will find for latitude 20°30′ the value 1248.945, and for latitude 30°25′ the value 1905.488. The difference, or 1905.488 — 656.543, is the value of the meridional arc between these latitudes, for which 1 minute of arc of the Equator is taken as a unit. On the projection, therefore, 1 minute of arc of longitude will measure $\frac{10\text{ in.}}{656.543} = 0.0152$ inch, which will be the unit of measurement. By this quantity, all the values derived from the table must be multiplied before they can be used on a diagonal scale of inches for this chart.

As the chart covers 14° of longitude, the 7° on either side of the central meridian will be represented by $0.0152 \times 60 \times 7$, or 6.38 inches. This distance can be laid off from the central meridian east and west on the upper and lower parallel. Through the points thus obtained, draw lines parallel to the central meridian, and these will be the eastern and western neat lines of the chart.

In order to obtain the spacing, or interval, between the parallel of latitude 21°00′ and the bottom parallel of 20°30′, find the difference between their meridional dis-

tances and multiply this difference by the unit of measurement, which is 0.0152.

Thus, $(1280.835 - 1248.945) \times 0.0152$
or $31.890 \times 0.0152 = 0.485$ inch.)

On the three meridians already constructed, lay off this distance from the bottom parallel, and through the points thus obtained, draw a straight line which will be the parallel 21°00′.

Proceed in the same manner to lay down all the parallels answering to full degrees of latitude; the distances for 22°, 23°, and 24° from the bottom parallel will be respectively:

$0.0152 \times (1344.945 - 1248.945) = 1.459$ inches,
$0.0152 \times (1409.513 - 1248.945) = 2.441$ inches,
$0.0152 \times (1474.566 - 1248.945) = 3.429$ inches, etc.

Finally, lay down in the same way the parallel 30°25′, which will be the northern inner neat line of the chart.

A degree of longitude will measure on this chart $0.0152 \times 60 = 0.912$ inch. Lay off, therefore, on the lowest parallel of latitude, on the middle one, and on the highest parallel, measuring from the central meridian toward either side, the distances 0.912 inch, 1.824 inches, 2.736 inches, 3.648 inches, etc., in order to determine the points where meridians answering to full degrees cross the parallels drawn on the chart. Through the points thus found, draw the straight lines representing the meridians.

If a Mercator projection is to be constructed on a piece of paper where the size is controlled by the limits of longitude, the case may be similarly treated.

TRANSFERRING DATA FROM ONE PROJECTION TO ANOTHER

You may have occasion to transfer data from one projection to another, such as from the polyconic to the Mercator or vice versa, or from the gnomonic to the Mer-

cator. In any case, this may be accomplished by carefully plotting the geographic coordinates of points on one projection and then locating these same points on the second projection. The method which is used to transfer a great circle route from a gnomonic chart to a Mercator chart may be used as an example of the method.

The following description of the method used is reprinted by permission from *Navigation and Nautical Astronomy* by Dutton, published by the U.S. Naval Institute, Annapolis, Md.

"Since the direction of a great circle is constantly changing, the course of a ship following such a track would have to be continually changed. As this is obviously impractical, the course is changed at intervals, so that a ship follows a series of rhumb lines. Since for a short distance a rhumb line and a great circle are nearly coincident, the result is a close approximation of the great circle track. This is generally accomplished by determining points at regular intervals along the great circle track, plotting them on a Mercator chart or plotting sheet, and steaming the rhumb lines between the points. * * *

"The Hydrographic Office publishes several charts on the gnomonic projection, covering the usually navigated portions of the earth. The point of tangency is chosen for each chart to give the least distortion for the area to be covered. We have seen that any great circle appears on this type of chart as a straight line. Because of this property, the chart is useful in great circle sailing.

"However, since the meridians are not shown as parallel lines, no ordinary compass rose can be provided for use in measuring direction over the entire chart, and since angles are distorted, they cannot be measured by protractor. Latitude and longitude at a particular point on the chart must be determined by reference to the meridians and parallels in the immediate vicinity of the point. Hence, a gnomonic chart is not convenient for ordinary navigational purposes. Its practical use is limited to solution of great circle sailing problems.

"In use, a straight line connecting the point of departure and the destination is drawn on the chart. The great circle is then inspected to see that it passes clear of all dangers to navigation. If this requirement is met, the courses are then transferred to a Mercator chart by selecting a number of points along the great circle, determining their latitude and longitude, and plotting these points on the Mercator chart. These points are then connected by straight lines to represent the rhumb line courses to be steered. The two arrows of figure 10–27 indicate a corresponding position on the two charts. It can be seen in figure 10–27 that points have been chosen at intervals of 5° of longitude to facilitate the picking off of points and plotting them on the Mercator chart. At this interval the error in using rhumb lines to approximate the great circle is small."

QUIZ

1. What is a sextant?
2. What type of instrument has largely replaced the lead-line and the sounding pole for taking soundings?
3. What does the plot plan, or location plan, for a location which has been chosen either for a natural harbor or for an artificial harbor show?
4. What methods are generally used in estimating the quantities for a dredging project?
5. (a) What is the datum for Navy installations for the Atlantic and Gulf coasts? (b) For the Pacific coast?
6. (a) When do spring tides occur? (b) Neap tides?
7 What Government agency publishes 5 volumes of tide tables annually?
8. (a) What is a tidal current? (b) What is a flood current? (c) What is an ebb current?
9. What is the brief period between flood and ebb current when there is no horizontal motion of the water perceptible?
10. (a) What is the direction of the tidal current called? (b) The velocity?

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11. Why is it necessary to plot the control on the master sheet for a hydrographic survey?
12. Why must control stations be plotted with great precision?
13. What method is usually used for plotting triangulation stations?
14. How are stations which have been located by a topographic survey usually placed on the master sheet?
15. What are cuts?
16. What is the boat sheet?
17. What is the most common method of plotting positions of soundings on the boat sheet and why?
18. What is the best test that can be applied in the field as to the accuracy of the meter scales?
19. What publication contains the elements for the construction of a polyconic projection?
20. What is a good construction check for the polyconic projection?
21. In the use of the Mercator tables, what is the unit of measurement which is used as an expression for the ratio of any one minute of latitude to any other?
22. Where can the true value of a minute of longitude at any latitude be found?
23. What method may be used to transfer data from one projection to another?

CHAPTER 11

ILLUSTRATIVE DRAFTING

INTRODUCTION

As a DMI 1 or C in the Navy, you should be prepared to plan the work for a complete illustrative drafting section, selecting the correct medium and method of presentation for a particular job. To do this, you must have a wide understanding of the field of illustrative drafting. You should understand the various printing processes, how to prepare copy for the printer, and the various methods of preparing artwork so that it can be reproduced efficiently by printing processes. You should know something of the methods of reproducing artwork which may be used in the drafting room itself, such as silk-screen, multilith, mimeograph. You should know the various types of charts and graphs and how to prepare them. You should understand composition and design, know the types of lettering, and how to use color to best advantage.

With this knowledge, it is not necessary that you be skilled at freehand drawing. The requirements of the Navy where illustration is concerned are not the same as the requirements of some popular magazine printed on slick paper. If you are talented enough to draw freehand figure illustrations or cartoons, you are fortunate, but it is more important that you be acquainted with the numerous drawing and rendering techniques avail-

able, that you understand techniques of reproduction, and that you are able to plan not only your own work but the work of others.

COMPOSITION AND DESIGN

According to the dictionary, composition is "the art or practice of so combining the parts of a work of art as to produce a harmonious whole," while design is defined as a "sketch of something to be executed, a delineation; plan," or "the arrangement of details which make up a work of art." The distinction between the two words is slight, and they are often used synonymously.

There are no hard and fast rules for composition. Each piece of artwork must be considered individually and composed in a manner best suited to its use. A poster should be brief and striking in composition and color, the elements few, and words and visual easily taken in at a glance, since a poster is something to catch the attention of the passerby. A chart or graph, to be studied, may be subdued and fairly detailed, and the information it contains should be presented in a straightforward manner so that there is no possibility of confusion. A technical illustration showing, for example, the major electrical parts affixed to an internal combustion engine may be quite detailed, but it will do its job more effectively if the engine block and nonelectrical components are shown in gray, while the electrical system is shown in black or a contrasting color.

However, there are certain principles which, modified to fulfill particular purposes, apply to every composition. One of these is the principle of unity; a second, the principle of equilibrium or balance; and a third, the center, or order, of interest.

When you have a piece of artwork to do, study the elements to be included to decide which is the most important. That one should be emphasized by placement or color so that it is the thing that first attracts the eye of the viewer. Decide which is the next most important ele-

ment, and plan it so that it will evoke the interest of the viewer next, and so on. Study the different elements to see how they may be arranged to balance each other so that the piece has equilibrium without disrupting the order of interest. When the proper equilibrium and order of interest are established, the composition will have considerable unity. However, it will pay you to study it again to determine whether there are any elements which can be eliminated, simplified, or played down in tone or size.

There is a mathematical proportion that is often useful to remember when you compose a piece of artwork. This proportion is known as the GOLDEN SECTION or SECTOR. It has also been called the IDEAL PROPORTION. Pythagoras, in the sixth century B. C., is said to have asked at what point a stick should be cut so that one piece would be in perfect proportion to the other. The cut would have to lie somewhere between one-half and one-third. The ideal proportion is shown in terms of lines in figure 11–1.

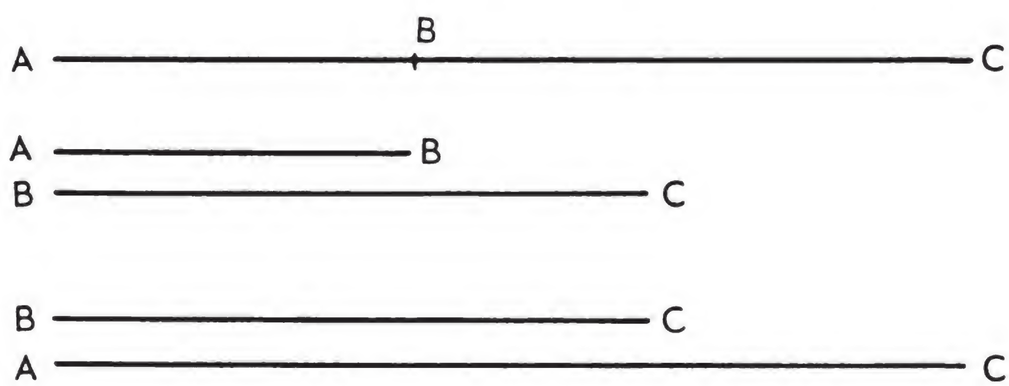


Figure 11–1.—The ideal proportion.

If a line AC is cut at B, the ratio of the line AB to the line BC is the same as the ratio of the line BC to the line AC.

REPRODUCTION PROCESSES

When a number of copies of a poster, training aid, or other piece of artwork are to be reproduced, the repro-

duction process will affect the method used to prepare the artwork. When the artwork is to be done in line only, and less than 100 copies are required, it may be reproduced by a photographic process, blueprint, ozalid, hectograph, or liquid duplicator. When more than 100 copies but less than 5,000 are required, it may be reproduced by mimeograph or silk screen. For more than 100 but less than 1,000, multigraph or multilith, a small offset press may be used. For more than 500, photo-offset lithography or letterpress printing are justified.

When there are photographs or other halftones to be reproduced, and less than 100 copies are required, artwork may be reproduced as photostats or ozalid prints. For more than 100 copies, the photogelatin process or photo-offset lithography may be used. For more than 2,500 copies, letterpress is justified. Rotogravure is too expensive to be used for runs of under 100,000 copies for either line or halftone copy.

Actually, in the Navy, the method of reproduction you choose will depend on the method which is available at your station, and the figures just quoted relate more to commercial reproduction. The most common methods of reproduction available in the Navy are discussed in the following sections. You may find that it is practical, if you are required to produce many posters or training aids in color, to make and learn to use a silk screen in the drafting room.

Silk Screen

For small quantities of a poster or placard in color or in black and white, the silk screen process is excellent. The reproduction may be done in the drafting room, using a minimum of equipment and materials, and the appearance of the poster produced, as well as the number of colors used, is limited only by the skill of the man doing the work. The materials needed for silk screen work consist of a frame, which may be made or purchased commercially, and which is hinged to a base; special silk

for the screen; material for preparing a stencil; silk screen colors; and a squeegee. One type of screen which may be used is shown in figure 11–2A, and a printing squeegee is shown in figure 11–2B.

Silk screen stencils are made by a number of processes. They may be made of paper or film and glued to the screen. Glue or imitation shellac may be painted on the silk screen to form a stencil. A sensitized silk may be used to produce a stencil photographically. Or the drawing may be done directly on the screen with liquid tusche and lithographic crayon. Glue is then applied to form the negative stencil and benzine used to remove the tusche and crayon. Commercially, a great many more processes are also used.

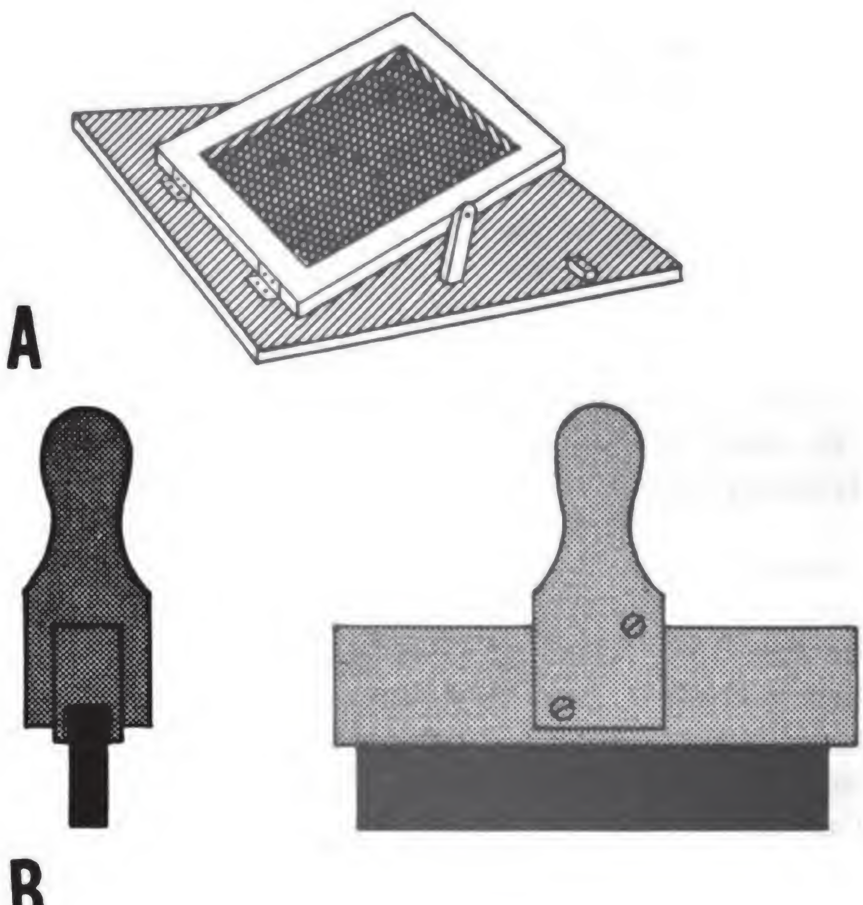


Figure 11–2.—A. Silk screen frame hinged to base. B. Squeegee used for silk screen printing.

The paper-stencil method is one of the simplest. A separate stencil is made on a sheet of thin, sturdy paper for each color to be printed. The paper should not be waxed or oiled. Any sharp knife may be used to cut the stencil, but a stencil knife is preferred. When several colors are to be printed, a master drawing should be prepared. The master drawing may then be positioned on the base under the screen. Then, either outline it carefully so that it can be replaced in the same rectangle, or mark crosses on four sides, part on the drawing and part on the base, so that by careful matching, the drawing can be replaced in position.

When the first stencil has been cut, place it on the master drawing and position the master drawing on the base under the silk screen. Next lower the screen and place a few drops of glue on the screen at the corners of the stencil. Remove the master drawing and replace it with the printing paper. The sheet of printing paper should be positioned against stops, as shown in figure 11–3, in order for all the colors to print in register.

Lower the screen again and place a small amount of process color on one side of it. With the squeegee, drag this color across the screen. The paint itself will make the stencil adhere to the silk, and wherever there is an opening in the stencil, the paint will penetrate through and print on the paper underneath.

Run as many prints as you need. Then remove the paper stencil. Lift the excess paint off the screen with a piece of cardboard. Clean the paint off the screen with benzine, and wash the glue, to which small pieces of the paper stencil may still adhere, from the screen with water. Repeat the entire process for the next color. If the master drawing is replaced in the same position under the screen each time a stencil is attached to the screen and the printing paper is checked against the stops carefully, the colors should print in perfect register.

The colors take some time to dry. Therefore, when a number of copies are being printed, you will need racks to dry them on.

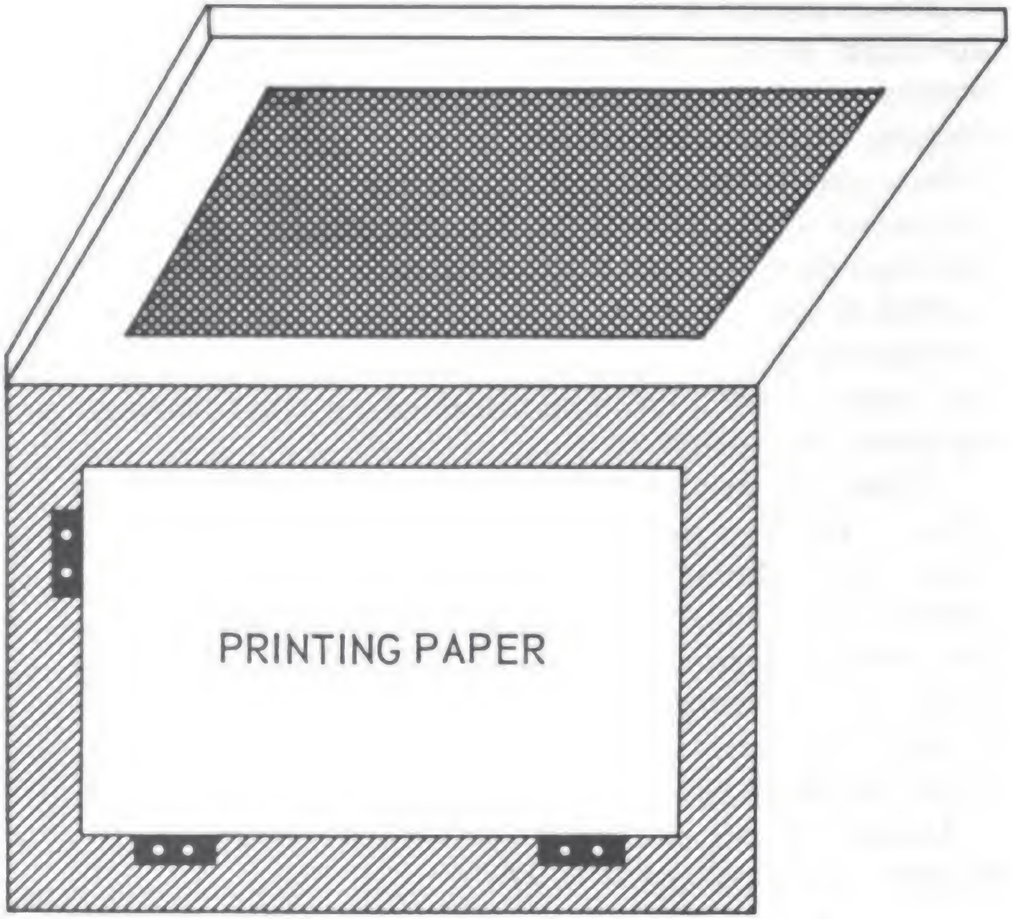


Figure 11-3.—Stops used to position printing paper under silk screen.

The silk screen stencil paper available commercially is a tough paper to which a thin film of lacquer is attached. Using a sharp knife, cut out and remove the film of lacquer from the image areas without cutting through the paper base. After the image has been cut out, place the stencil face up under the silk and daub it lightly with cotton dipped in lacquer thinner. The thinner melts the lacquer film just enough to cause it to leave the base and fuse with the mesh of silk.

As you can see, artwork to be printed by the silk screen paper stencil method, should be designed for stencils printing flat colors. Both opaque and transparent colors are available, and by overprinting with transparent colors

very unusual effects can be obtained. Greater variation and texture can be obtained on the silk screen when the liquid tusche and lithographic crayon are used, but this method requires considerable artistic skill.

Duplicating Machines

Most machines for printing or photographing visual material are actually duplicating machines, but such methods as mimeographing, multilithing, and multigraphing, are more generally referred to as duplicating methods.

MIMEOGRAPHING is a stencil process. Line drawings can be made on the stencil by cutting away the top surface or coating on the stencil sheet with a stylus. Styli are available in the loop type, the ball point type, and the wheel type. Lines are usually not as sharp as inked lines, and when a line is drawn across another line, the stencil sheet may tear. To prevent this, place a sheet of thin cellophane on the stencil and draw the second line on top of the cellophane.

Lettering guides are available for cutting letters, and shading may be done by the use of screen plates. These are placed under the stencil sheet, which is then rubbed with the stylus, so that the coating comes off the stencil in a pattern of dots.

A mimeoscope, a box with frosted glass top and a light inside, is useful when you prepare mimeograph stencils. A transparent writing sheet is placed between the stencil and the glass, and drawings which are on thin enough paper for the light to penetrate can be placed under this sheet and copied.

MULTIGRAPHING is a method for printing from raised surfaces. The machine is equipped with a slotted drum. Letters are inserted in the slots, and illustrations can be used if they are converted into special curved electrotypes, nickel plates, or rubber plates.

MULTILITHING is done on a small offset press. It repro-

duces material prepared on the paper or metal plates from which it prints. These plates can be prepared by hand or photographically like regular offset plates. However, the inking mechanism cannot handle a large enough flow of ink to print large solid areas of ink well, and these should be avoided.

Ozalid

Ozalid machines and materials are available to most Navy drafting rooms. Ozalid is a dry copy process which produces positive prints directly from positive originals and exactly the same size as the originals. A number of different papers have been developed for use in reproducing by this process. For long runs, aluminum offset plates, which may be used on offset duplicators, are available.

When a piece of artwork is to be reproduced by ozalid, it must be prepared on a translucent paper, on vellum, or on tracing cloth. For good line reproduction, a carbon backing paper can be used during the preparation on translucent paper. When the lines of the drawing are impressed on both sides of the translucent paper, any light that might leak through in the reproduction process is blocked. In this way, a good clean pencil drawing can be reproduced by ozalid with fairly sharp lines.

Standard ozalid papers include a card which may be used for posters. It is available to print in black or blue on a white base or in black on a blue, buff, cherry, or salmon base.

Translucent papers and foils are also available, some with special coatings which provide lines of great opacity so that they will reprint well. OZACHROMES are transparent films with images in blue, red, yellow, and black, which may be made directly from separation positives for lithographic color proving and also used as color overlays in presentations and diagrams. OZACHROME VIEWFOILS are films with images in vivid red, blue, green, orange, and black and may be used in light-beam projectors or view-

graphs to display charts, graphs, and other visual aids on screen and walls. When several colors are desired on either ozachromes or ozachrome viewfoils, the original for each color must be prepared separately and printed separately. OZALID DRYPHOTO is a grainless, gelatin-coated paper for reproducing continuous-tone photographic subjects in a warm sepia color. Excellent photoengravings may be made from DRYPHOTO'S well-defined images.

Photo-Offset Lithography

In the photo-offset lithographic process, the copy for reproduction is first photographed with a process (copying) camera. The image on the negative may be reduced or enlarged or made the same size as the original. Textual copy is also photographed. It may consist of reproduction proofs pulled from type set exactly as for the letterpress process, or it may consist of typewritten material. Text copy may also be prepared on special machines which operate like typewriters but which have regular type faces and justify lines like a typesetting machine.

After the negative is made, proofs may be taken from it by one of the contact printing methods like blueprint or ozalid. If no proof is required, the negative is used immediately to make a lithographic plate by contact printing. The lithographic (zinc) plate is coated with a light sensitive solution that hardens wherever it is hit by light during the exposure. After the exposure it is covered with ink and then soaked in water. The water dissolves the unhardened portions of the coating, leaving only the inked-over, light-hardened image areas on the plate. These areas take ink when the plate is run on the press while the other areas remain clean.

On the offset press, the inked image from the plate offsets or prints onto a rubber blanket covering a large cylinder. The image on this rubber blanket is then transferred to the paper which is carried on another cylinder.

It is still possible to make corrections after you receive blueprints (proofs) of a piece of artwork to be printed by photo-offset lithography. The printer, or stripper, can cut out areas of the negative if this is requested. The negative may easily be trimmed to a smaller size. And additions may be made, either by scratching the surface of the negative or by stripping in a piece from another negative. Such work is time consuming, however, and unless the corrections are very important, usually considered too expensive.

Tone art is photographed just like line art, except that a halftone screen is used in the camera so that the tones are reproduced as a series of dots. Halftones require three exposures instead of one, the first for highlights, the second for detail, and a third for tone in the dark areas. This makes them slightly more expensive than line illustrations.

If art is to be printed in more than one color, it must be either prepared with an overlay for each color, or color separation negatives must be made by using special filters in the camera. Remember that both letterpress and offset printing require a separate plate and press run for each color to be used.

Letterpress

Letterpress is one of the oldest processes of reproduction. In this process, the text is set up in metal type and placed in long trays called galleys. The type proofs taken from these trays are called galley proofs. Artwork is etched on metal plates called cuts which are mounted on wooden blocks. Cuts are made by a process known as photoengraving. It is similar to the offset platemaking process, except that the nonprinting areas of the plates are etched out, leaving the image standing in relief.

Metal type and cuts are assembled together and locked or wedged into metal frames called chases. They are then put on the press where the raised surfaces are inked. As the press operates it presses the inked sur-

face against the paper to produce printed impressions. It is sometimes possible to distinguish work that has been printed by letterpress from that printed by lithography because the letterpress type generally produces a slight impression on the back of each sheet.

PUBLICATION DESIGN

Many of the underlying principles of layout are the same regardless of whether the job is to be in the form of a pamphlet or a book. These same principles also apply with slight variation to layout and copy preparation for newspapers and magazines. However, newspapers and magazines have their own special techniques for putting the material together so as to emphasize what is important and to make an attractive page.

A more detailed discussion of newspaper and magazine layouts (makeup) is given in the *Armed Forces Newspaper Editor's Guide,* NavPers 10293–A. A more detailed discussion of book makeup is given in *Printer 1 & C,* NavPers 10458, or *Lithographer 1 & C,* NavPers 10454.

Page Size and Shape

Printing paper is manufactured in rectangular sheets, and it is more economical to cut and fold them in rectangular shapes. When a sheet of paper is folded once and then trimmed, it makes 4 pages. Folded three times, it makes 16, and four folds make 32. Pamphlets and books should be designed around these units, which are called signatures.

You should try to select a page size that can be cut out of a stock sheet with the least amount of waste. In determining the shape of your page, remember that rectangular forms have the most pleasing proportions. Those most commonly used are the printer's rectangle, which has the proportions of 2 to 3; the golden mean rectangle, with proportions of 3 to 5; and the hypotenuse rectangle, which has proportions of 5 to 7. You can vary these pro-

portions slightly, if necessary, in order to arrive at a shape that cuts best from the stock sheet.

STANDARD TYPE PAGES AND TRIM SIZES USED IN THE NAVY

Size of trimmed book (inches)	Bleed	Type page (picas)		
		Size, not including bottom folio [1]	Number of columns	Column width
[2] 5⅞ x 9⅛	No	28 x 46	Two	[3] 13½
5⅞ x 9⅛	No	26½ x 46	One	26½
5⅝ x 8¾	Yes	28 x 44	Two	[3] 13½
5⅝ x 8¾	Yes	26½ x 44	One	26½
7⅞ x 10¼	No	41 x 53	Three	[3] 13
7⅞ x 10¼	No	39½ x 53	Two	19
[4] 7⅞ x 10¼	No	37½ x 53	Two	18
7⅝ x 9¾	Yes	41 x 52	Three	[3] 13
7⅝ x 9¾	Yes	39½ x 52	Two	19

[1] Page depth as given must include running head if one is used.
[2] The width is always given first.
[3] Use only 8-point or small-faced 10-point type for measures 14 picas or under.
[4] Exception will be made in case of loose-leaf publications, which will be 7¾″ x 10¼″.

Figure 11–4.—Some standard sizes and shapes.

The table shown in figure 11–4 lists some of the standard type page and trim sizes used for Navy publications.

Dimensions of the Type Page

The type area should follow the proportions of the page. Use long lines on wide pages and short lines on narrow pages. In fine-quality bookwork, printers often divide the page half and half between type and white marginal space. They have found that type matter occupies one-half of the page when the width of the type is 71 percent of the width of the page and the depth of the type is 71 percent of the length of the page.

In determining the size of the type page, you must consider economy of production and length of copy, as well

as appearance. In some publications, it is not practical to divide the page equally between type and marginal space. For example, reference books and texts ordinarily require more text area and less marginal space. Margins should never appear crowded, however. Narrow margins make reading difficult.

If the book has a long running head, or one that is used with a rule, it should not be included in the dimensions of the type page. Short running heads are generally excluded. Folios and classifications lines, such as CONFIDENTIAL are never considered as part of the over-all depth of the page.

The back or inner margin of the book page is usually made narrower than the others so that when the book is opened, the gutter of white space down the center will appear to be equal to the width of either of the outside margins. The top margin is slightly larger than the back margin; the outside margin is larger still; and the bottom margin is the largest of the group. Layout men position the type on a page by the use of a diagonal line, as shown in figure 11–5, or they may simply position the type by sight, placing it slightly above the center vertically and slightly off center toward the binding edge horizontally.

You will see publications which do not have margins conforming to the rules given above. These are usually designed as special luxury editions or as attention catchers. For these, the rules of good art layout apply. The essential characteristic should be a pleasing appearance, achieved by a careful balancing of white space, type, and illustrations.

Designing Individual Pages

Many layout men begin with a page of text, but you can begin with the cover, title page, or almost any other page—just so long as you follow the same pattern for each one. A central theme will tie the pages together and make them look like parts of the same book.

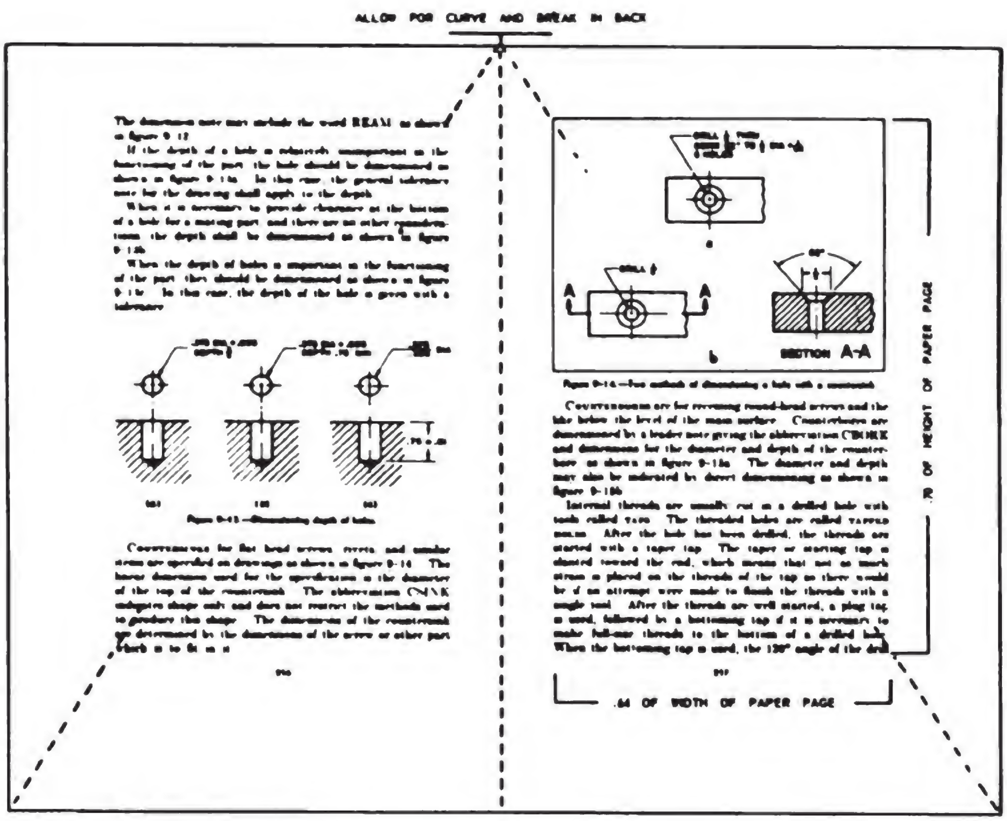


Figure 11–5.—Method of determining margins for a book.

Only a rough thumbnail sketch is needed at the start. You should make several sketches until you come up with an idea that you like. In making these roughs, look for the most important element and build your design around it, keeping in mind, of course, the requirements of legibility and good spacing.

Once you have attained an acceptable sketch, take another sheet of tracing paper and draw up the job to actual size. This sketch may also be rough, because you still may not be satisfied with the first draft. You may wish to change it again and again before you finally hit on a satisfactory arrangement.

When the rough arrangement meets your approval you can work it into a finished layout. Place a sheet of tracing paper over the rough and trace off the various elements, squaring them up with the T-square and triangle as you

go along. All elements should now be carefully positioned. You must show the exact sizes of cuts and the exact amount of space allotted to the type. Spacing must be definite and accurate.

A single illustration is generally placed at the top or just above the optical center of the page, but since two facing pages are used as the unit of layout in bookwork and called a SPREAD, you must consider both pages in planning your design. Most layout men agree that the right hand page should outweigh the left. Therefore, when you have only one cut, you should place it on the right page. If you have two large, square-finished illustrations of the same size, you may use one at the top of each of the two facing pages or at the bottom.

If the page format consists of two columns, single column illustrations fare better if they are placed in the outside corners of the page, or if they are stepped, as shown in figure 11–6. Two-column illustrations look better at the top or bottom of the page.

When single-column cuts are narrower than the column of type, or if they do not have a square outline, you should try to square up the page by running four or five lines of type above (and sometimes below) the illustration.

If two-column illustrations do not have a square outline, try to place them at the bottom of the page. When they are placed in the center of the page, the text matter should not be doubled up as it is when two-column heads or tables occur in the center of the page. Since all breaks, such as these, tend to confuse the reader, you should avoid them whenever possible.

Legends are usually set the full column width regardless of the width of the cut. One- or two-line legends may be centered, but legends of more than two lines are ordinarily set with a hanging indention.

You can use BLEED ILLUSTRATIONS to provide interest. A bleed illustration is a picture that runs off the page when the publication is trimmed, and you must allow for

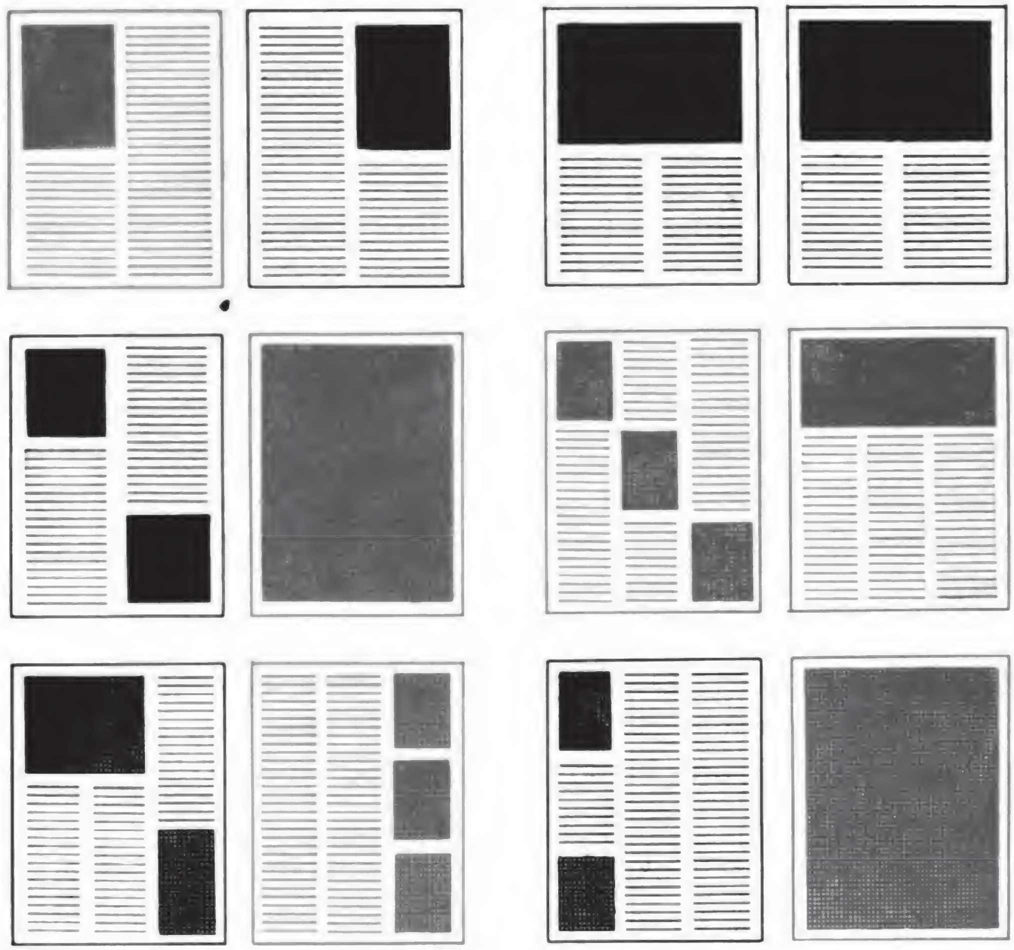


Figure 11–6.—How to position illustrations on facing pages.

this trim in cropping the artwork. (See fig. 11–7.) When there are small illustrations, it is better not to bleed them, unless you group them in a panel and allow the panel to bleed.

A cover design may consist of ILLUSTRATIONS AND TYPE, or it may consist of HAND LETTERING AND TYPE, or it may consist simply of TYPE.

The simplest kind of cover, of course, is the one that is composed of type alone. In some cases, the same type form is used—perhaps with a few minor changes—for printing both the cover and the title page. As a rule, however, the type used for the cover is larger and flashier than that used for the title page.

Figure 11–7.—Bleed illustrations can be used to add interest to the job.

Since long titles often look awkward when they are set in large type, you should confine your titles to five or six words, if possible. If the type is well arranged and of a size sufficient to give the display required, almost any face may be used, although the choice is sometimes affected by the historical period referred to or the feel of the message of the text. Then, too, if the publication is one of a series, the cover design should match that of others in the series.

HAND LETTERING may be used effectively for five or six words of copy. However, unless it is well done, it is not as good as type. Calligraphy, the art of lettering, is a speciality in itself, and it should be performed only by qualified artists. Even the best artists have to re-do the lettering two or three times to get the exact effect required.

Photographs are sometimes used effectively as cover designs, but unless they are lively and interesting, they tend to make the cover dull and commonplace. (See fig. 11–8.)

There are many ways to make your type design interesting. For example, shaded backgrounds or reverse

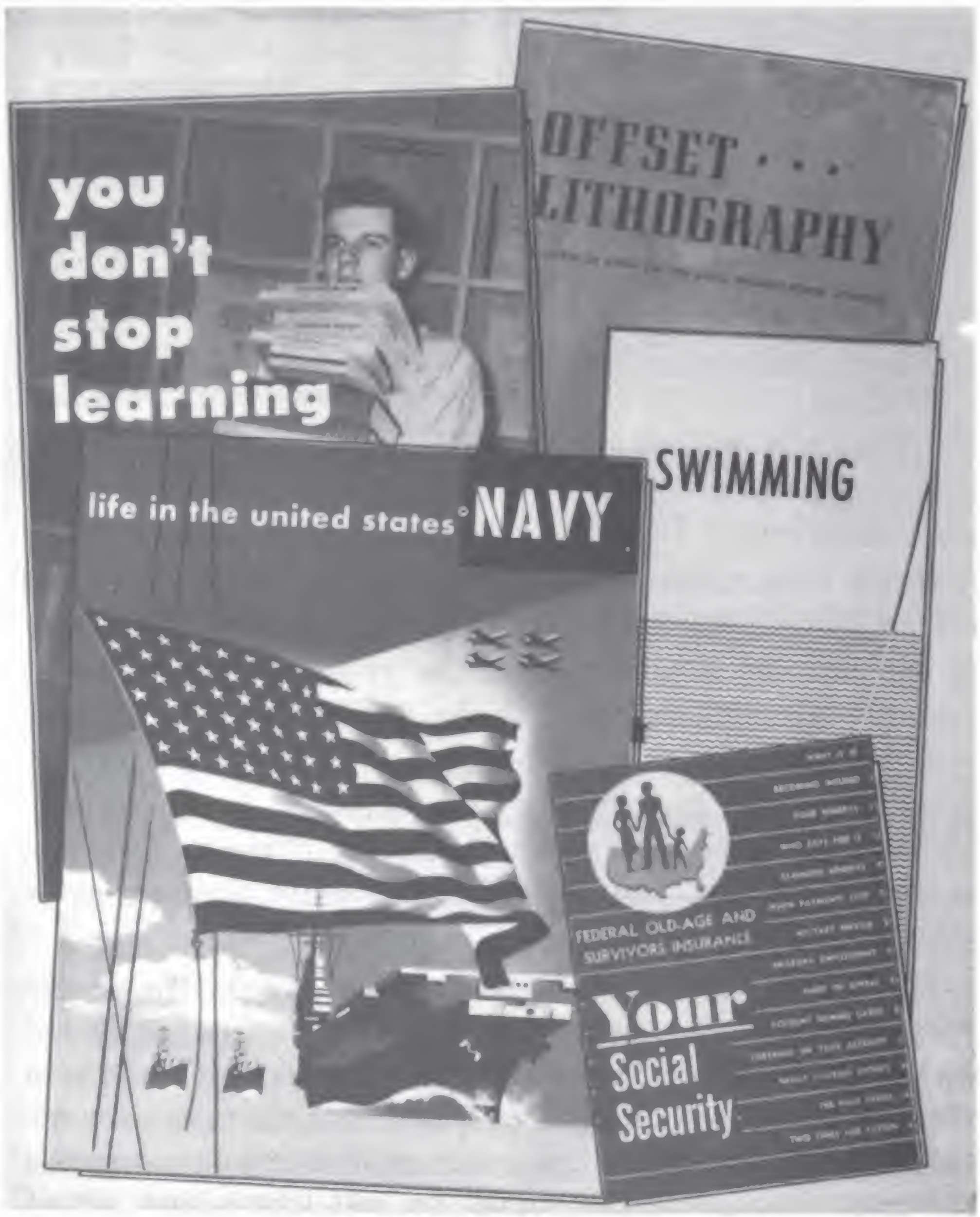


Figure 11–8.—Interesting cover pages.

(white on black) lettering is pleasing. You can also inject life into the cover by printing with colored ink on white stock or with black or colored ink on colored stock.

Markup

After you have drawn up a complete and accurate layout, your next step is to write in the instructions to the printer. You should indicate the size and kind of type, the leading (spacing) desired, and the dimensions of the type areas. The width and depth of the areas for cuts should also be shown, as well as the kind of illustrations to be used and any reductions and enlargements that are to be made. Show where each piece of artwork is to go on the layout by marking the same number on both the layout and the art.

You should also mark in the margin of the layout the trimmed page size, the size of the type page, and the classification, if the book is classified. Figure 11–9 shows two methods of preparing copy and marking the layout.

In addition to marking up the layout sheet, you must transfer certain of these marks to the manuscript, so that the compositor can follow the instructions when he sets the type.

Preliminary Dummy vs. Pasteup Dummy

You can make a complete and detailed layout for each page in a book, showing all elements properly positioned. The printer will follow this preliminary layout (called the DUMMY) when he sets the type and again when he makes up the pages for the book.

However, if the copy is exceedingly long, it may not be feasible to try to determine the number of pages it will fill. Therefore, instead of making up a complete layout for every page in the book, you may simply make layouts for key pages, such as the cover and title page, some of the front pages, one or two of the text pages, and one of the chapter head pages. These key pages will set the style

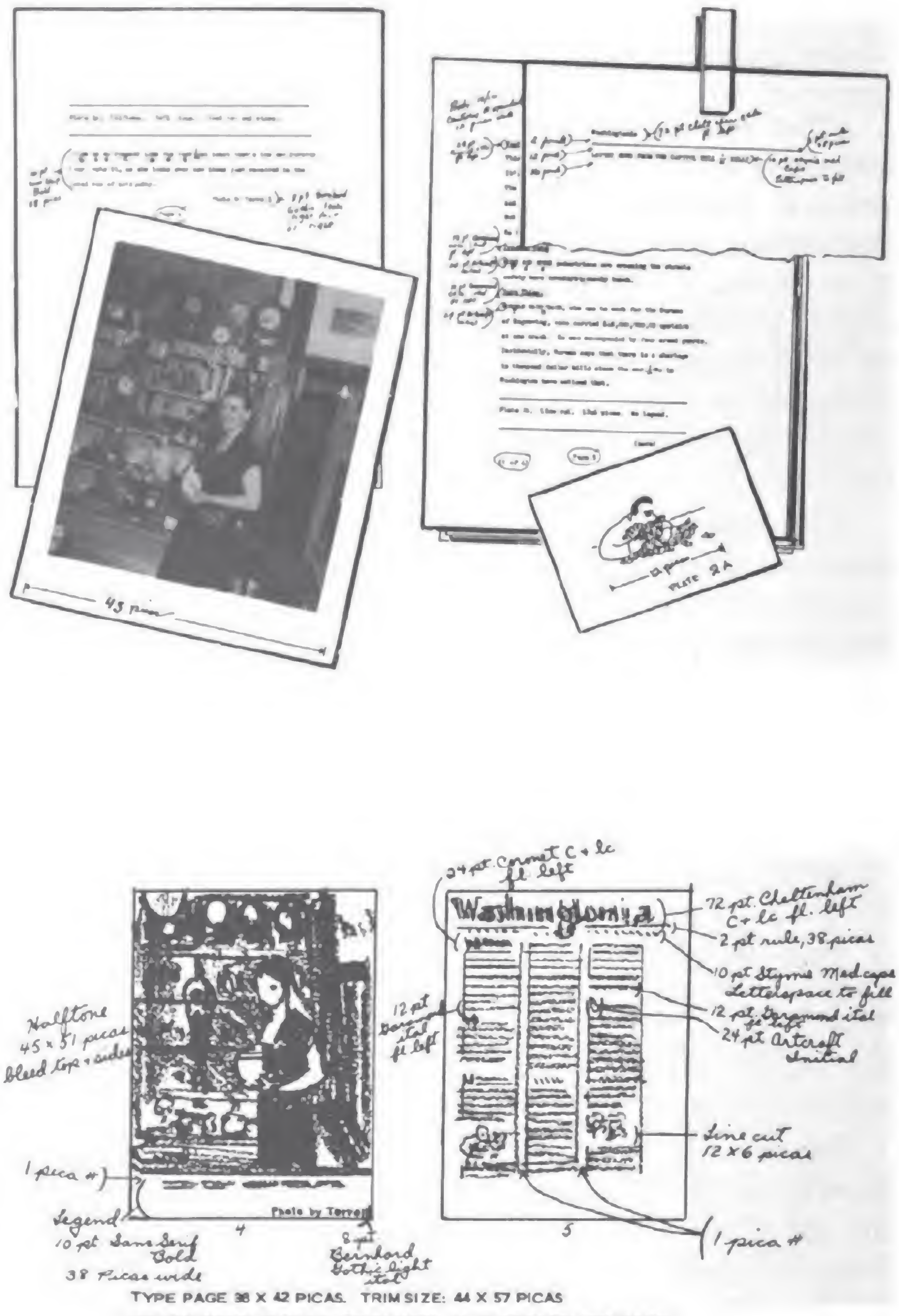


Figure 11-9.—Methods of indicating areas for illustrations and type.

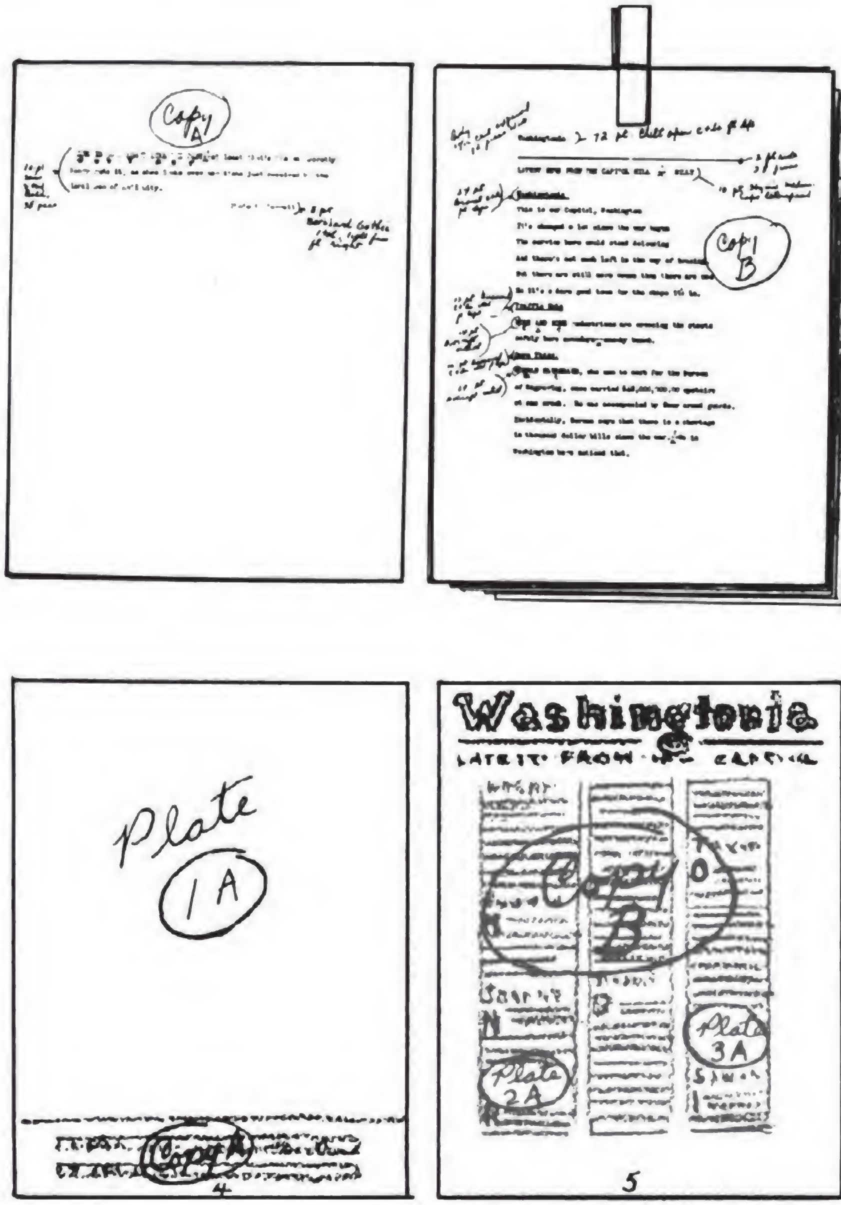


Figure 11–9.—Methods of indicating areas for illustrations and type—continued.

for the entire job and will serve as a guide to the printer when he sets the type.

The bulk of the layout work in this case will come after the type has been set. When you receive proofs of the

type and illustrations, trim them and paste them in their proper positions on individual page layout sheets. When you have finished, you will have a pasted-up layout sheet for each page in the book. The printer will use these individual layout sheets (known as the PASTEUP DUMMY) as a guide in positioning text and illustrations when he makes up the pages.

ILLUSTRATIONS

Illustrations for use in publications may be of several types. When you prepare these illustrations, no matter what type they may be, it is essential that you keep the format of the particular publication in mind at all times. No matter how excellent the artwork, it will fail in its purpose if it must be reduced so far that it is illegible or if it is the wrong shape to fit in the space available for it in the publication.

Drawings for publications may be done in black and white, tone, or color. Black and white line drawings may be reproduced as line cuts. Line cuts are cheaper and more easily made than halftones, and are far cheaper to reproduce than color. Various methods are used for producing shading in black and white drawings and these have been discussed in some detail in *Draftsman 3*, NavPers 10471.

Illustrations may be used in publications to relieve the monotony of the printed page, to catch the eye, to tell a story, to reinforce ideas in the text, to influence the emotions or suggest action, or to convey information and show procedures and methods. Engineering drawings which adhere to well defined drawing conventions in orthographic, isometric, or oblique projection may be used as well as freehand or mechanical perspectives. Drawings are excellent for showing a sequence of steps or relationships of various parts in a schematic style. Cutaway drawings or a combination of a photograph and

a drawing may be used to show the interior or hidden parts of a machine.

When engineering drawings are to be reproduced in a publication, some alteration may be necessary. They are usually too large to fit in a standard format, unless it is possible to print them as TIP-INS. (Tip-ins are separate sheets of paper glued into place in a signature when the book is bound.) Also engineering drawings often include manufacturing instructions, or other material, which are not needed when they are used as illustrations.

The first step in preparing an engineering drawing for reproduction in a publication consists of obtaining a print of the drawing. On this print, material which is not necessary may be marked out and any information which is needed, such as labels, may be added. Then a new drawing should be made. This may be made on a blueline print or as a tracing. On this drawing, the lines should be heavy enough and the lettering large enough to reproduce well. Lettering need not be made freehand but may be applied as reproduction proofs or by any other suitable method.

Other types of drawings for use as illustrations should be planned just as carefully. Often a shading effect which looks good on the original will be unsightly on reduction because white spaces become so small that they fill up with printer's ink. Or if lines are made too light, the illustration will appear like a hole on the page and fail to hold its own with the text or headings.

When photographs are used as illustrations, they are reproduced as halftones. For methods of cropping and sizing photographs, see *Draftsman 3*, NavPers 10471. A photograph often contains material which does not add to the effectiveness of the composition. By cropping, this can be eliminated and important portions of the photograph emphasized. (See fig. 11–10.) Cropping requires picture sense, the ability to visualize the finished illustration.

Figure 11–10.—Photograph before and after cropping.

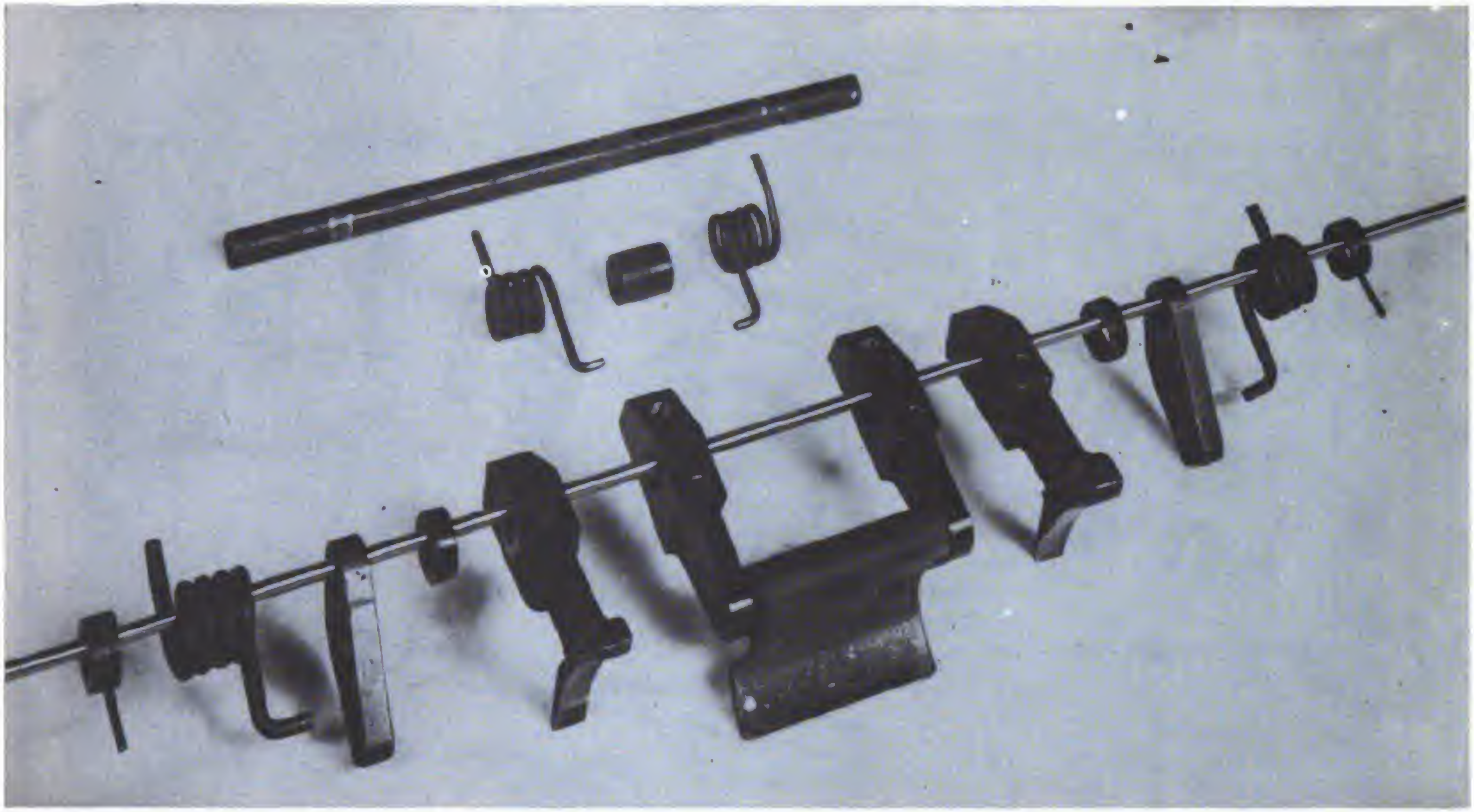


Figure 11–11.—Making an exploded-view photograph.

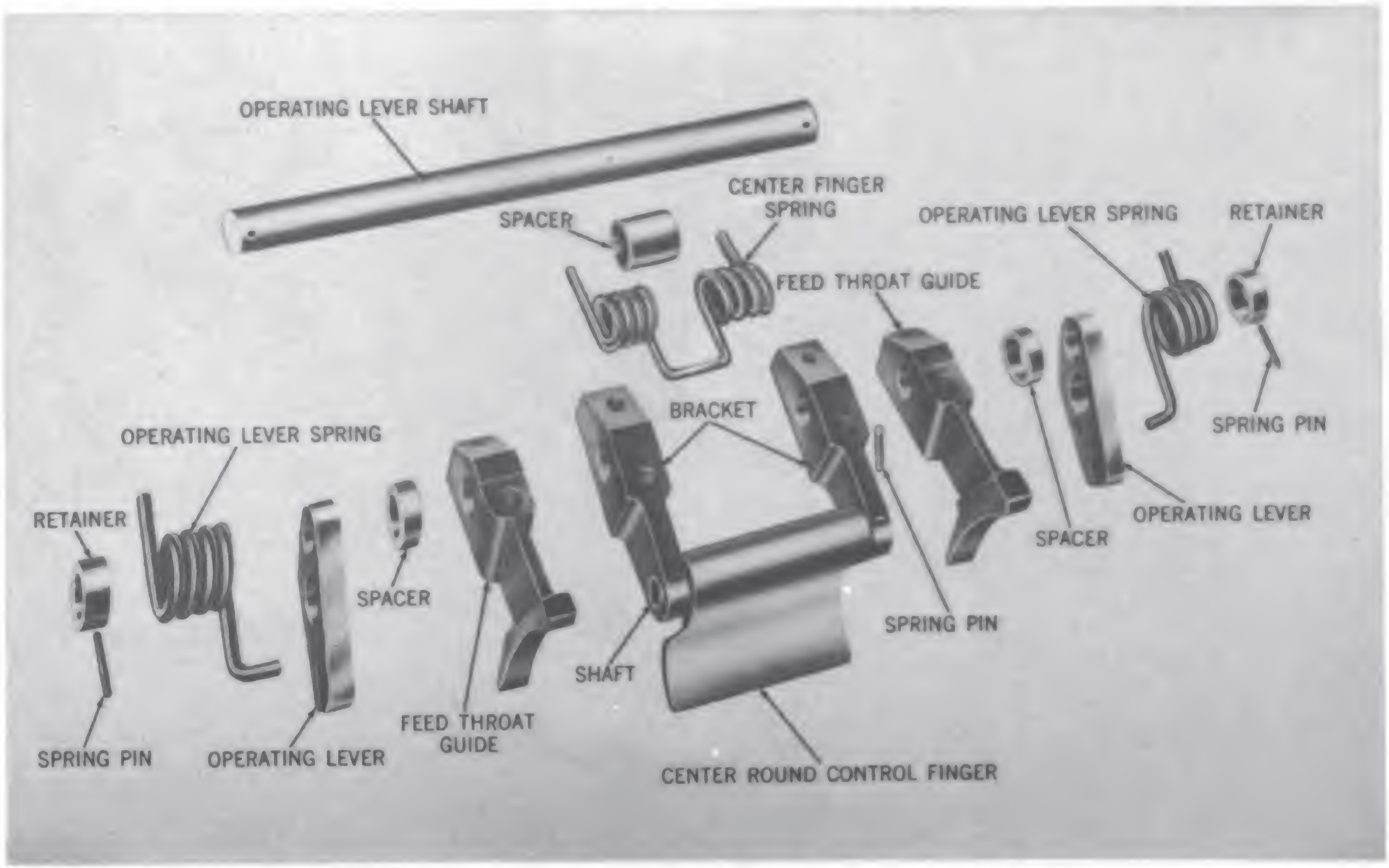


Figure 11-11.—Making an exploded-view photograph—Continued.

For good reproduction, photographs often need to be improved or altered by opaquing or retouching. A pen, a brush, or an airbrush may be used. Blemishes may be corrected; undesired portions of the picture may be blotted out; and the contrast improved. Figure 11–11 shows the method by which an exploded view photograph may be made and then retouched with the background opaqued and the individual pieces finished at the bottom. Figure 11–12 shows a closeup photograph before and after retouching. Figure 11–13 shows a photograph which would be greatly improved if the background were opaqued, eliminating irrelevant material.

When arrows and captions are to be used with a photograph, they are often placed on an overlay. The resulting

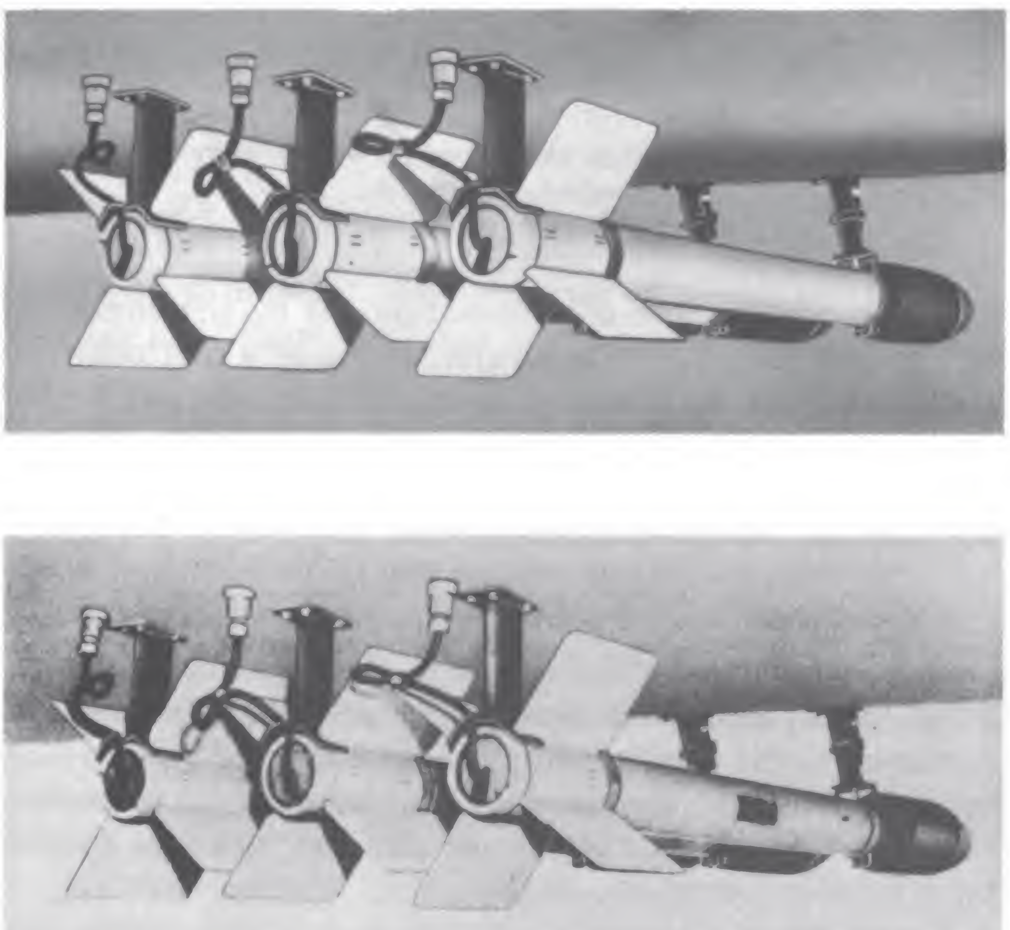


Figure 11–12.—Closeup photograph—retouched and unretouched.

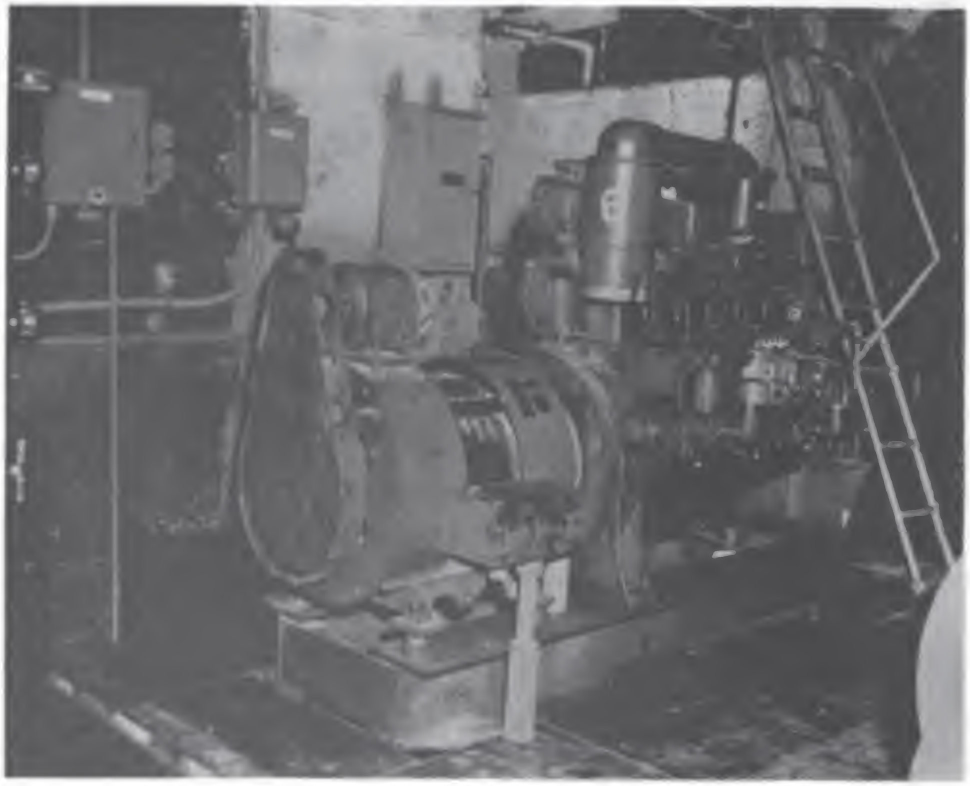


Figure 11–13.—Photograph in which the subject is obscured by irrelevant background material.

art is then made into a combination cut by the engraver or lithographer. The photograph is shot as a halftone and the arrows and captions are shot as a line. The two negatives are then printed together on the plate and the unscreened arrows and lettering will appear blacker than the dark portions of the photograph.

POSTERS

The poster is a distinct art form. Too often it is treated as an illustration with text. Such treatment ignores the purposes of the poster, which are to attract attention and get a message across quickly. The lettering on a poster should be a part of the design and the message should be as brief and clear as possible.

There are a number of simple techniques which are very effective for posters. Even if you are not an accom-

plished illustrator, you can compose excellent posters using these techniques.

First decide how your poster is to be reproduced. Its purpose and the number of copies required will have a lot to do with that decision. If only one is needed for classroom use in a training program, you can use any art technique you desire in rendering it, but the simplest and quickest is preferable. If a dozen or more are needed for local use, it may still be best to design the poster for reproduction with a stencil and airbrush or some other quick rendering technique. Or it may be reproduced by ozalid on one of the poster boards available, in which case you need to draw the original on translucent paper and to the correct size to fit the board. If more are needed, they may be reproduced by silk screen or lithography.

One of the simplest techniques consists of drawing a simplified silhouette, such as a silhouette of a couple dancing for a dance poster. You can work from an illustration or a photograph to get the correct proportions and the action. When you have a silhouette you like, trace its outline on a piece of colored paper or make several silhouettes on different colored paper and try these out on your poster board. Combined with cut-out letters, which are available commercially, this can make a very interesting poster.

The silhouette may also be used as a pattern for a painted or printed object on the poster, or indicated by stipple or airbrush effects. Figure 11–14 shows a very effective and simple poster of this type.

Another simple technique is called the flat patch technique. It can be reproduced very effectively by silk screen, and many poster artists use it, especially to create posters for movies. The usual method is to start with a photograph of the subject. This may be enlarged to the desired size by using a projector. The outlines of the subject are then traced including outlines between different tone

Figure 11–14.—Poster using simple silhouette.

Reprinted with permission from "Poster Design" by Biegeleisen. Copyrighted 1945 by the Greenberg Corporation.

Figure 11-15.—Movie poster using flat patch technique.

areas. The result may look something like a jigsaw puzzle. It is usually best to use no more than five or six colors. When a figure is to be reproduced, three of the colors may be flesh tones graded from a light to a dark. An example of the use of this technique is shown in the poster in figure 11–15.

TRAINING AIDS

One of the most important jobs, as far as the Navy is concerned, is the preparation of training aids. This is a job which can require all of your ingenuity. Training aids are not merely illustrations to make a dull lecture palatable. They often provide the most important step in the training process, the link between the description of the process and the doing of it. They also may be used to motivate the student, to provide an incentive to learning.

Many types of training aids are used in the Navy. These include posters, flannel board graphics, slides, transparencies, film, displays, and three dimensional models. The first decision when a training aid is required will be which type to prepare. A number of things will affect this decision. For one thing, it is useless to prepare a training aid which cannot be used because the equipment for presenting it is not available. Slides, transparencies, and film all require special projectors. The number of copies of a training aid needed will also affect this decision. Also the potential life of the training aid will be a big factor.

In order for training aids to be used to their fullest advantage, a few basic rules should be remembered. Visual aids should be clearly visible to all members of the group. All lettering and figures should be large and simple. Material should not be crowded. In the case of charts, for example, it is better to make an additional chart, providing plenty of room for printed material, than to try to squeeze a great deal into a single chart at the cost of legibility. Use sharp contrasts of color—

black on white, black on yellow, or the reverse of each—to make for easiest legibility.

Flannel-Board Graphics

A flannel-board graphic is a variation of the poster and it is especially adapted to training. The separate parts are prepared on cloth-backed paper, as shown in figure 11–16. The instructor can then use a build-up technique, placing one part at a time on the board, and explaining its importance fully before putting the next part into its proper place. Not until the final step is discussed is the picture completed, as shown in figure 11–17.

The flannel board should be constructed with a felt or flannel material that has a fuzzy or long nap. For ozalid reproduction, cloth-backed sensitized paper, ozalid EX-105MC can be used. The cloth backing of this paper adheres to the flannel very effectively. It requires no additional treatment and is ready for use in its original form

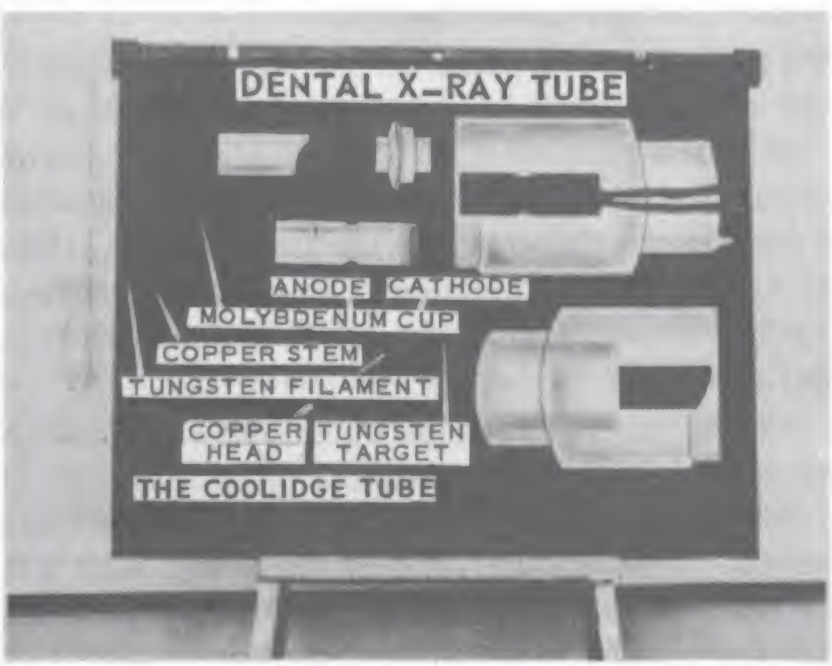


Figure 11–16.—Parts of flannel-board graphics.

Figure 11–17.—Parts in place to make the finished graphics.

immediately after it is dry printed. The graphics can be printed in positive or in negative.

Original artwork should be prepared using black india ink on a good grade of tracing paper. Masters of any size may be prepared photographically by enlarging or reducing any existing material. Acetate lettering has been found advantageous for use in preparation of either paper or photographic masters. In order to produce lines on the flannel board, different colored yarns, which adhere to the flannel, can be used.

A variation of this method consists of covering a building board with acetate. Colored scotch tape may be used for lines. The lettering and illustrations are prepared on light weight illustration board and attached to the acetate with double way (adhesive on both sides) scotch tape. After the poster has been used, you may pull the design off the acetate and use the base again.

Slides and Strip Film

Both slides and strip film are often very effective as training aids. The smaller size of slides, 2 inches by 2 inches mounted in cardboard, are made with film which is the same size as one frame of a strip film. The artwork should be made 6¼ by 8 inches or 8 by 10 inches or larger, just so the proportions remain the same. It can then be photographed with a 35-mm. camera. For the slides, either a negative or a positive print may be used.

When a film is to be produced, all the artwork should be made the same size. After it is photographed, it is printed on a roll of film, and this positive roll is called a strip film. When this is run through a projector, the operator moves it up one frame at a time. Usually the 2- by 2-inch slides cannot be shown in a projector for strip film, although some projectors are adapted for both purposes.

When artwork is to be prepared for color slides or color film, it is wise to talk to the photographer who will make the film. Color film varies in the way it reproduces color. Some film tends to have a bluish cast and other film to reproduce certain colors better than others. In any case, it is better to use dark or dull colors for the background and only to use a brilliant color for an important spot. Black and white artwork reproduced on color film produces pleasing brownish-gray tones.

The 3¼ by 4-inch size is the standard lantern slide. These slides consist of a sandwich of two pieces of glass with or without a filler of film, which is bound by tape around the edges. Artwork to be photographed for use in these slides should have the same proportions as that to be used for the 2 by 2-inch slides. Either a negative or a positive print may be used, or the photographic print may be made directly on the glass. When color is required, this plate may be dyed or painted with photographic dyes or paints. Paint the emulsion side of the glass with a brush and build up the color areas to the required tone

by successive washes. Transparent color films may also be made from colored artwork.

Handmade lantern slides may be prepared, using one or another of the following materials; etched glass, plain glass, plastic sheets, carbon-backed acetate, and clear or colored cellophane. Plain glass may be coated with a clear (household) gelatin to provide an excellent surface for india or colored inks. Glass marking pencils will be required with plain glass, but lead pencils and crayons will serve with etched glass. Cellophane may be obtained in several colors. It is used to provide silhouettes and for typed titles to hand drawn materials on glass. Amber cellophane is frequently used to diminish the glare of clear glass slides.

Glass and transparency should be thoroughly cleaned before binding operations begin. If gum tape is used for binding, a few drops of glycerine added to water is recommended to retard evaporation from the moistened tape and to permit more time for binding before the gummed surface dries. One part of glycerine to eight parts of water is a good proportion. A method of binding is illustrated in figure 11–18. An ink spot or other suitable marking on

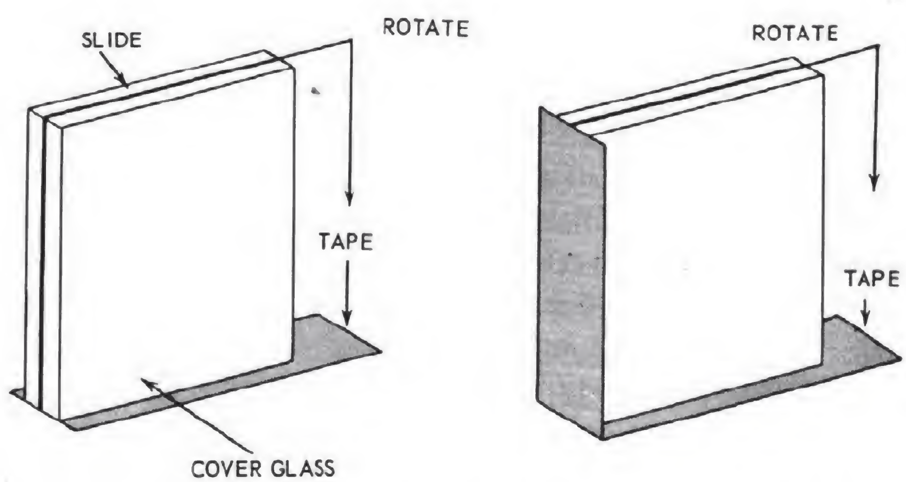


Figure 11–18.—Binding glass slides. Tape is folded down around edges of slide and sealed.

the lower left hand corner of the binding tape will assist the projectionist to locate the spot to hold when he inverts the slide before placing it in the projector.

Transparencies

Probably no training aid has become so widely used in such a relatively short period of time as transparencies. These may be prepared for several different types of machines and mounted in frames which vary in size. The over-all size after mounting is usually 10 inches by 10 inches.

When you start to prepare transparencies, you will do well to make a layout for each frame on tracing paper to the exact size the finished transparency is to be. If these are worked out in sufficient detail, the actual separation drawings may be assigned to someone else.

If a subject is complex, then either a series of transparencies or a number of overlays should be used. For a series, care should be taken to ensure that material contained in one transparency is related to the others in the series so that the presentation has the quality of unity throughout. Methodical presentation may be obtained by presenting an orienting illustration and then getting down to details in subsequent transparencies. When overlays are used, the representation may be started by showing the basic cell, and each overlay laid over it in order, until the entire illustration is assembled. This method is especially effective for showing the cumulative stages of assembly or disassembly of such things as guns and machines.

The method used to produce the artwork for transparencies and the size at which it is prepared depend on the way in which it will be reproduced. It may be made actual size for reproduction by ozalid or it may be made a larger size and reduced photographically to the preferred size.

For conference briefing or command briefing use, where quality of reproduction is desired, the transparen-

cies are usually made photographically. Check first, however, to be sure that your photographic section is prepared to do this work.

For photographic reproduction, artwork should be made in black on white paper and at least one-third larger than the final size. Prepare a separate drawing for each color separation to be made, using registration marks to be sure that all units will register properly after they are printed. Then mark on each separate drawing the reduction required and the color. After they are reduced, the drawings are printed on color-treated acetate and assembled, either as a single transparency or as a transparency with overlays for use in a viewgraph. (See fig. 11–19.)

Transparencies may also be printed by the ozalid dry-printing process. In this case, the originals should be made on transparent paper, tracing cloth, or vellum in black ink or in an opaque medium such as a grease pencil. When more than one color is desired, a drawing should

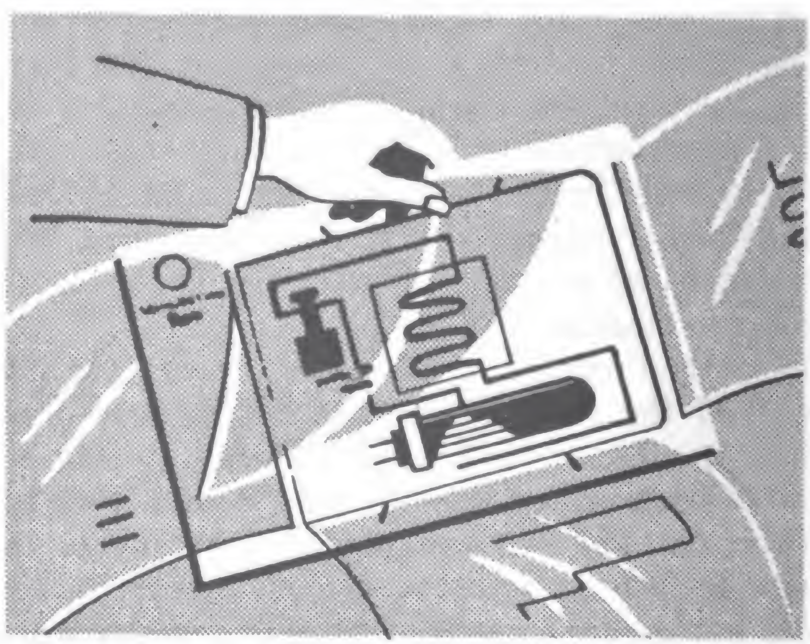


Figure 11–19.—Transparency prepared with overlays.

be made for each separate color. All work must be made the same size as the final transparency. Since with this method of reproduction there is no reduction in size, transparencies made by it usually do not appear as finished as those which are reproduced by photography.

In the ozalid process, the transparencies are reproduced on sensitized acetate which has been treated to print in color. Each separation must be printed separately and handled carefully until it is dry, since as long as it is wet it will smear. The separate color sheets may then be combined and mounted either as a single transparency or as a transparency with overlays. (See fig. 11–20.) The translucent master drawing may be used to make paper copies for distribution to the members of a class.

A third method of duplicating transparencies is by fluid duplicators. The materials required consist of a frosted sheet of acetate, an aerosol-type plastic coating, and fluid duplicator carbons which come in purple, blue, green, red, or black. Either a duplicating machine or a fluid process (Standard or Ditto) machine may be used. The master drawing should be made the same size as the final transparency on a fluid duplicating master paper without a carbon backing. Then for each separate color, insert the appropriately colored carbon and trace the parts of the picture desired in that color until the entire drawing has been traced. Put the master on the duplicator and run a copy on the frosted side of the plastic sheet. Finally spray the plastic sheet copy evenly and lightly with aerosol-type plastic coating to make it transparent. As with the master drawing for ozalid reproduction, the master drawing may be used to make paper copies for distribution to a class.

In an emergency, drawings or designs may also be made directly on cellophane, plexiglass or lucite, or clear or matte acetate, using a grease pencil, transparent inks or india ink. Areas to be colored with ink should be outlined with a fine grease pencil. This will keep the inks

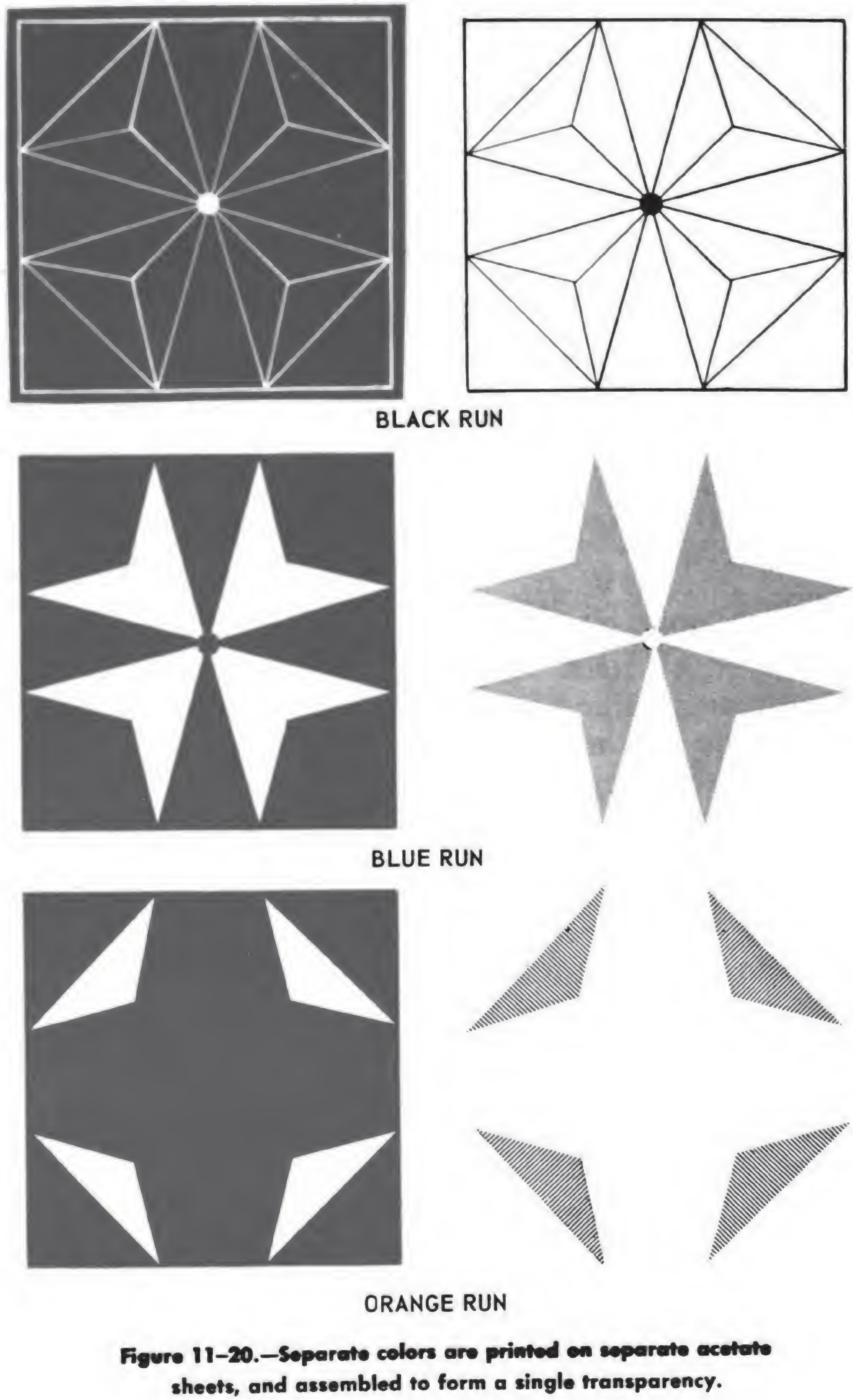
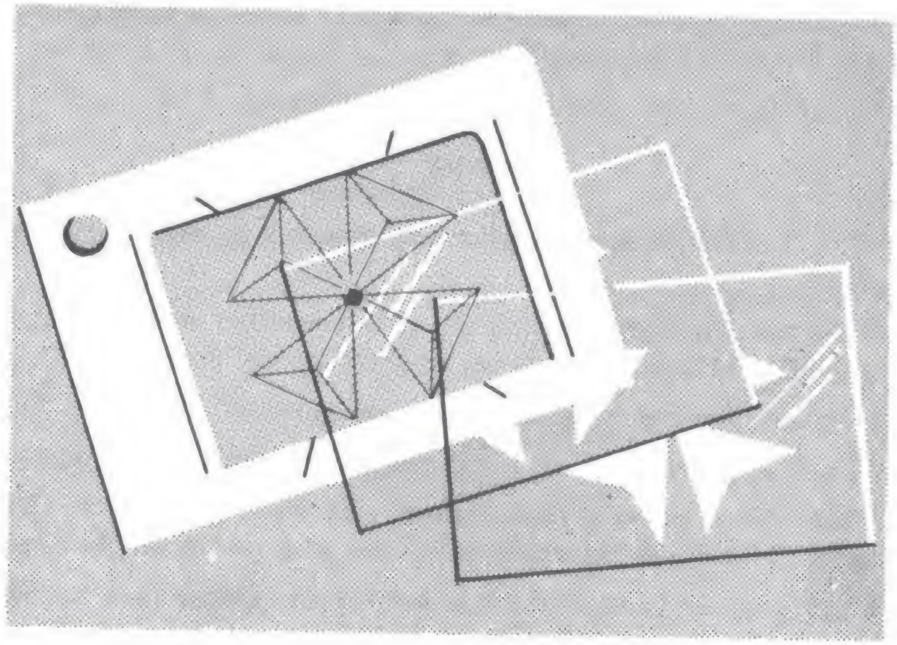


Figure 11-20.—Separate colors are printed on separate acetate sheets, and assembled to form a single transparency.



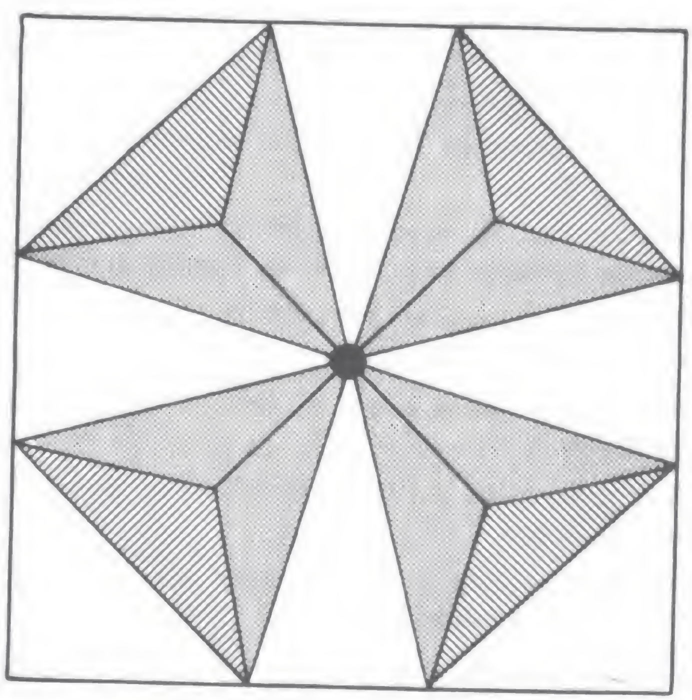


Figure 11-20.—Continued.

from running. Commence coloring from the center area and work toward the grease pencil line. One color of ink should dry before another is applied. Undesirable markings may be washed off.

QUIZ

1. Why should a poster be brief and striking in composition and color?
2. What are the three principles of composition which, modified to fulfill particular purposes, apply to every composition?
3. In inexact figures, what is the ideal proportion?
4. Why is a knowledge of reproduction processes important?
5. What reproduction process, which may be used in the drafting room, is excellent for small quantities of a poster or placard?
6. What are the basic materials needed for silk screen work?
7. What determines the number of stencils to be prepared for one poster in the silk screen paper stencil method?
8. How should artwork to be printed by the silk screen paper stencil method be designed?
9. What are the methods of reproduction generally referred to as duplicating methods?
10. How are line drawings made on a stencil sheet for mimeographing?
11. What method can be used to prevent a mimeograph stencil from tearing when a line is drawn across another line?
12. When illustrations are to be used in material to be multigraphed, what do they have to be converted into?
13. Why should large solid areas of ink be avoided in material to be multilithed?
14. How must a piece of artwork, which is to be reproduced by ozalid, be prepared?
15. What is the first step in reproducing artwork in the photo-offset lithography process?
16. Is it possible to make corrections on blueprints of a piece of artwork to be printed by photo-offset lithography?
17. How is artwork prepared for reproduction by letterpress?

18. What is a signature in a book?
19. What is a spread in a book?
20. What is a bleed illustration?
21. Why is it essential that you keep the format of the publication in mind at all times when you prepare illustrations?
22. Name two important things for which training aids can be used?
23. What are the two sizes of slides?
24. What is the maximum size for a transparency?
25. What methods may be used to duplicate transparencies.

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER I

THE NAVY DRAFTSMAN

1. Since the number of men in the Navy are limited in peacetime, the specialization of duties within a rating must be limited.

2. The five emergency service ratings into which the Draftsman rating may be divided under mobilization conditions are: Mechanical Draftsman (DMM), Structural Draftsman (DMS), Electrical Draftsman (DME), Topographical Draftsman (DMT), and Illustrators (DMI).

3. The rates DM3, DM2, DM1, and DMC correspond in general to the following work levels common to civilian drafting: tracer (DM3), detail man (DM2), layout man (DM1), and chief draftsman (DMC).

4. The general requirements for advancement in rating may be found in *BuPers Manual 1948*, part C, chapter 7, section 2, C–7201 through C–7210, and a summary of them is given in the chart at the front of this book.

5. The specific military requirements for advancement in rating may be found in the Manual of *Qualifications for Advancement in Rating*, NavPers 18068 (Revised), and they are discussed in the Navy training courses on the military requirements.

6. The professional requirements for Advancement in rating to Draftsman 1 and C may be found in the *Quals Manual* and in the Navy training course *Draftsman 1 and C*, and they are discussed in this course.

7. *Training Publications for Advancement in Rating*, NavPers 10052, lists under each separate rating the publications on the basis of which the general service examinations are constructed.

8. Current publications of military drafting standards are listed in the current issue of the *Index of Specifications and Standards (used by) Department of Navy, Military Index,* volume III.

9. Current Navy training courses are listed in the latest edition of the *List of Training Manuals and Correspondence Courses,* NavPers 10061 (Revised).

CHAPTER 2

ADMINISTRATION

1. The *Organization Manual of the Department of the Navy,* NavExos P–861B, describes the standard Navy format for organization charts.

2. If the same drawing number is assigned to two different drawings, the number on one of the drawings must be changed.

3. Classified tracings are kept in locked files.

4. Out-of-date prints should be destroyed.

5. The most important consideration when a reproduction machine is to be placed in a room consists of ensuring the best possible ventilation.

6. Manufacturer's instructions should be adhered to in order to ensure the safety of personnel and the efficient operation of the machine.

7. Supplies of sensitized paper and other materials for the reproduction room should be kept in a dehumidified, cooled storage area, such as a photo supply room if one is available.

8. Reproduction materials stored in the reproduction room should be kept in a light-tight space to preserve sensitivity.

9. Only as much developing solution should be prepared at any one time as is necessary for immediate use, because all developing solutions contain acids or form poisonous fumes which are detrimental to anyone coming in contact with them.

10. If ammonia is not in a nonshatterable container it should be transferred to another container.

11. When someone is exposed to ammonia fumes even temporarily, he may be temporarily blinded.

12. If you are composing a letter for the signature of your commanding officer or officer-in-charge, you should refer to the *Navy Correspondence Manual.*

13. A supply survey is used whenever naval property must be condemned, appraised, or declared nonexistent because it has been lost or stolen.

14. A definite sequence of checking procedure and a checklist of points are advisable in order that a thorough job of checking can be done, omitting no aspect of the drawing.

15. Revisions of drawings are made when they have been requested by someone in authority after use of the drawing has proved that there is an error in it or if an improvement has been suggested.

CHAPTER 3

AUXILIARY VIEWS AND PERSPECTIVE DRAWINGS

1. The two projection methods in use in engineering drafting are perspective or projection and parallel projection.

2. Parallel projection differs from perspective projection in that the projectors instead of converging are kept parallel.

3. Parallel projection can be divided into oblique projection and orthographic projection.

4. An auxiliary view is used when a surface on the object is inclined to as much as two of the principal views or when the surface is inclined to all of the principal views.

5. (a) A primary auxiliary view is hinged to the plane of the view to which it is perpendicular. (b) It may be hinged at any angle between the other principal views and will fall between them.

6. The chief purpose of an auxiliary view is to show the inclined surface on the object in its true shape and dimensions.

7. A partial auxiliary view showing the inclined portion of the object is all that is needed.

8. They may be used to aid in the construction of foreshortened principal views.

9. When it is desired to find the proper width of a surface in another view without projecting lines from it.
10. It is necessary to draw a secondary auxiliary view when it is a view of the surface on the object which is inclined to the surfaces of all the principal views.
11. In revolution, the object is revolved in a principal view until the inclined surface on it is parallel to another principal view.
12. Perspective projection is often used for exploded views of objects because it shows how the object looks to an observer, and all the different parts and their relation to each other are therefore easier to comprehend at a glance.
13. There is only one vanishing point used in one-point perspective and that is what gives it its name.
14. A line or a plane is drawn full size in a perspective projection drawing when it is considered as resting against the picture plane.

CHAPTER 4

MECHANICS, STATICS, AND STRENGTH OF MATERIALS

1. Force is action upon a body which tends to set it in motion or to change its state of motion.
2. When work is done, a resistance is overcome by a force acting through a measurable distance.
3. Quantities may be classified as scaler quantities and vector quantities.
4. Four examples of types of vector quantities are displacement, velocity, acceleration, and force.
5. The force which represents two or more forces acting on a particle is called the resultant.
6. When only two forces are acting on a particle, the parallelogram of forces or the triangle of forces may be used to find the resultant.
7. A known resultant is broken down into components.
8. When more than two forces are involved, the polygon of forces, or force polygon, is used to find the resultant.

9. A problem in vectors can be solved graphically, if it contains not more than two unknowns.

10. Statics is that branch of mechanics which is the study of the equilibrium of forces.

11. All arrowheads point in the same direction in a triangle of forces in equilibrium, while in a triangle which shows forces not in equilibrium, the arrowhead of the vector representing the resultant will point in the opposite direction from the arrowhead of the other two vectors.

12. A centroid is the center of gravity of a body.

13. A couple is formed by two forces which are parallel, equal, and opposite, but which act at different points on a body so that they tend to produce rotation.

14. The moment of a couple is measured by taking the product of one of the forces multiplied by the distance between the two which is called the ARM of the couple.

15. The three formulas which define the conditions for equilibrium are: $\Sigma H=0$; $\Sigma V=0$; and $\Sigma M=0$.

16. When the component forces form a right triangle, the resultant may be found by solving the triangle using the following equation: $c = \sqrt{a^2 + b^2}$.

17. The component forces which form an angle other than 90° are usually solved by being resolved into rectangular components and solved either graphically or mathematically.

18. The elastic limit of a material is the point at which a force applied to the material becomes so great that the deformation in the material starts to become permanent.

19. The deformation which is caused in a material by an applied force is called STRAIN.

20. The resistance set up in the material by an applied force is called STRESS.

21. The ratio between stress and strain is called the modulus of elasticity.

22. Ultimate strength is the point at which a material will break under an applied force; endurance limit is that point below the elastic limit at which a material fails by rupturing when it has been subjected to many repetitions of a load.

23. The mechanical properties of a material have a great deal to do with whether undue distortion or breakage occurs under the loads carried by a member.

24. Loads may be dead loads, consisting of static loads, or they may be live loads consisting of impact loads or of repeated loads, or they may be a combination of one or several of these.

CHAPTER 5

MACHINE DRAFTING

1. Layouts should be made to as large a scale as possible because of the accuracy required.
2. The fast start and stop involved produce considerable shock.
3. Harmonic motion is the type shown by the sine curve.
4. Constantly accelerated and retarded motion produces a parabolic curve.
5. (a) A jig is a device which is not fastened to the machine but is fastened to the work and guides the tools.
   (b) A fixture is a device which is fastened to the machine and holds the work to be machined.
6. Spur gears may be distinguished by the fact that the teeth are cut squarely across the outer rim of the gear blank in a direction parallel to the gear shaft axis.
7. The working depth of a spur gear tooth is equal to 2 divided by the pitch.
8. Bevel gears have teeth cut on an angular face for transmitting motion between shafts that are set at an angle to each other but are in the same plane.
9. Bevel gears with shafts at right angles may be called miter gears.
10. Worm gearing is used when a large reduction in velocity is desired or when considerable increase in mechanical advantage is required.
11. The teeth of helical gears are cut across the outer rim of the gear blank at an angle to their axis, so that they are similar to the thread of a screw.
12. Belts and pulleys are used for transmitting mechanical power for some distance and flat belts may also be used for conveying material.

13. The sum of the pitch diameters of each pair of steps must be constant for step cone pulleys so that the length of the belt remains constant when it is shifted from one step to another.

14. Idler pulleys are used as belt tightening devices, belt guides, and belt conveyors; they may also be used on V-belts when V-belts are used as clutches.

15. A quarter-twist flat belt drive may be reversible only if guide pulleys are used.

16. A parts list should, ordinarily, give the name, quantity, material, stock size or weight, Navy stock number, or drawing number of each part included in the drawing.

CHAPTER 6

MECHANICAL DRAFTING

1. A standard plumbing system consists of water service pipes, building drains, and building storm drains, if required, from their connections in the building to points 5 feet outside, including all pipes, fixtures, vents, branches, devices, rain leaders, and connected storm branches.

2. The pipes used for water within a building are commonly galvanized steel with screw threads or copper tubing with soldered joints.

3. The kind of pipe used for waste and soil pipe below ground within the building and 5 feet outside the outer walls is cast iron with bell-and-spigot ends and caulked joints.

4. Waste and vent stacks are galvanized steel with screw threads.

5. Pipe sizes up to 12 inches in diameter are designated by nominal inside diameter.

6. The threads, both external and internal, are cut to a taper of 1 in 16, or 0.75 inch per foot, measured on the diameter and along the axis.

7. Pipe threads are represented by the symbols for screw threads.

8. The main reason traps are used in plumbing systems is to prevent sewer gases from entering buildings by way of the pipes.

9. Valves are installed in plumbing systems to control a fixture or a group of fixtures so that the entire system will not become inoperative when work must be done at a specific location.

10. The types of pumps commonly used in plumbing systems are the piston and the centrifugal.

11. The normal procedure in making takeoffs for bills of material is to start at the farthest end from the outside connections, or at the farthest fixture, taking off quantities of fixtures and scaling the piping.

12. Heated water rises to the top and cooler water takes its place because heated water is lighter than cool water.

13. Relative humidity is the ratio between the amount of moisture in the air and the amount of moisture necessary to saturate the air.

14. The use of the two pipe direct return hot water heating system should be avoided because of the unequal lengths of the circuits through the various radiators which means that special piping must be used and the first radiators in the system throttled in order to assure uniformity of radiator temperature.

15. The most efficient modern method of installation for radiators and convectors are long, low, finned tubes at the baseboard level.

16. (a) Warm air registers are usually placed low in the wall so that hot air will not be blown directly on the occupants of the room at a level that falls within the comfort zone. (b) Warm air registers are placed in interior walls so that cold exterior walls may be blanketed with a layer of warm air.

17. Cold air return registers are located at baseboard height so that the heavy cool air which collects in layers on the floor may be returned to the heating plant.

18. Radiant heating is the system of space heating in which large surfaces of rooms, such as floors, ceilings, walls, or a combination of these, operating at relatively low surface temperature, are employed to heat the space.

19. Electric strip heaters or electric unit heaters may be used in electric heating.

20. A split heating system is one in which steam or hot water radiation is combined with a forced warm air heating and ventilating system.

21. A separate drawing is made of the mechanical equipment when its indication on the building detail drawing itself would be confusing.

CHAPTER 7

STRUCTURAL DRAFTING

1. Record drawings are the final drawings made after a structure is built, which show the actual "as-built" construction.
2. It should be complete enough to convey to the designer information on space and functional arrangements, type of construction and material, and special details required by the design.
3. The first step in making an estimation of the materials needed for a job consists of a listing of the materials made directly from the detail drawings and the specifications.
4. Different materials are sold in different units and when an item is listed in terms of the wrong unit, too much or too little of the particular item may be delivered at the job.
5. Steel for floating structures is listed in terms of long tons consisting of 2,240 pounds.
6. A board foot is the equivalent of a board 1 foot long by 1 foot wide by 1 inch thick.
7. Concrete is measured as fixed or placed in the structure in cubic yards or cubic feet, except that molding, curbs, gutters, etc., are often measured by lineal foot with the other dimensions given so that the number of cubic yards or cubic feet may be found.
8. The proportions of a concrete mix are usually expressed as three numbers, thus, 1:2:4, with the proportion of cement first, the proportion of sand second, and the proportion of gravel or crushed stone third.
9. A square of roofing is a unit of 100 square feet.
10. The types of airfield drawings which may be required are structural drawings, such as floor plans, record drawings, preliminary drawings, and drawings for temporary structures or for minor additions to structures, and also drawings of the runways, taxi ways, and hard stands.
11. The base line plane extends horizontally from an established point at the bottom of the ship, usually along the top of the flat keel.

12. Waterlines are a series of lines which are established at different levels above the base line for convenience in making vertical measurements.

13. (a) The buttock planes are imaginary planes which pass through the ship outboard from the centerline and are used in making transverse measurements. (b) The buttock lines are formed at the intersections of the buttock planes with the hull.

14. The frame lines are a set of lines between the forward and after perpendiculars, which are numbered progressively from fore to aft.

15. The three plans used to show the complete shape of a ship are the plan view (or half-breadth plan), sheer plan, and body plan.

16. The designer's waterline is the waterline at which the ship has been designed to float.

17. A ship is said to have been designed with a drag when she has a slightly greater draft aft.

18. Camber is the slight curvature which is built into a deck.

19. The rows of fore-and-aft plating which make up the shell of a warship are called STRAKES.

20. The three parts of the keel are the central vertical keel, the dished or flat keel plate, and the rider plate or keelson plate.

21. (a) AH–206–L would be located in the forward division on the port side of the half deck above the second deck and used as a living space. (b) A–206–2A, a subdivision of a watertight compartment, would be located in the forward division on the port side of the second deck, and used for storage. (c) B–3–2E,

a subdivision of a watertight compartment, would be located on the starboard side of the ship at the bottom and used for machinery.

22. In aeronautical drawings, it is customary for principal views to be taken from the left side of the airplane.

23. The two basic types of construction applied to aircraft are the truss type and the monocoque type.

24. The cables, rods, bell cranks, etc., which connect the controls to the control surfaces are called the flight control linkage.

25. When lowered, the flaps increase the lift and drag of the wings, enabling the pilot to reduce airspeed in a landing, and they can also be used to give extra lift to the wings when the plane is taking off.

CHAPTER 8

ELECTRICAL DRAFTING

1. Alternating current is better than direct current for use where power is to be transferred over long distances, because transformers can be used in AC systems to change the ratio between voltage and current, and with a high voltage and low current in the circuit, smaller wires can be used and there is less heat loss.
2. Two types of AC systems are three-wire and four-wire.
3. A four-wire distribution system would be found with a Y-connected alternator.
4. Drawings showing actual as-built conditions are called Record Drawings.
5. The place where the wires of an electrical circuit enter a building is called a service entrance.
6. When two of the wires in an interior wiring circuit carry 230 volts and a third wire is neutral, electrical devices rated at either 230 volts or 115 volts may be operated.
7. Since the neutral wire is grounded, it is no longer a live wire, and there is no need to break its circuit at the service switch.
8. DC distribution systems are installed in submarines, small surface vessels, and large auxiliary vessels with considerable deck machinery that requires DC service for its operation.
9. The first letter tells how many conductors are in the cable.
10. It is a method whereby a heavy line is used to illustrate all of the cables in a run with the individual cables fanned out and identified at terminating points.
11. In the Navy, nonmetallic sheathed cable, called Romex, and armored cable, called BX, are the main types of wiring cable used.
12. A transformer, or induction coil, is used to increase the distance range of a simple telephone circuit.
13. On many advanced bases, you will find a battery-operated system that must be rung by hand and which is similar to those formerly used very widely in rural communities.
14. Five pieces of telephone equipment found in practically every telephone switchboard are cords, plugs, jacks, signals, and keys.

15. One distributing frame in a switchboard office is called an MDF or main distributing frame and an additional frame is called an IDF or intermediate distributing frame.
16. Three types of protective devices placed in lines, both at the substation and the switchboard office, are heat coils, fuses, and lightning arresters.

CHAPTER 9

TOPOGRAPHIC DRAFTING

1. The precision of measurement standard for a survey is usually expressed in terms of 1 divided by a number.
2. A traverse is closed if it begins and ends at the same point or, in other words, is a closed polygon.
3. The lengths of the courses of a traverse are usually stated in feet and decimal parts of a foot.
4. An azimuth is the angle measured clockwise between north and the direction of a course.
5. (a) A deflection angle is one that is measured from the prolongation of the preceding course. (b) If the angle is turned clockwise from the prolongation of the preceding course, it is a right deflection angle. (c) If it is turned counterclockwise, it is a left deflection angle.
6. The formula for the sum of the degrees of the interior angles in a polygon is $180° \ (n-2)$ where n is the number of sides.
7. The algebraic sum of all the deflection angles for a course should equal 360°.
8. (a) Bearings are measured from the south for the two south quadrants of the compass and from the north for the two north quadrants. (b) The letters preceding and following the bearing define the quadrant of the compass in which the angle falls, N for north, E for east and S for south, W for west.
9. $120°03'$ or $119°63' -$ N $65°51'$ W $=$ N $54°12'$ E.
10. In order to find the bearing of a course from the observed interior angle and the bearing of a previous course, the angle should be measured to the left, not from the bearing, but from the reverse bearing.

11. (a) The vertices of the angles of a traverse are referred to as the angle points of horizontal control. (b) Horizontal control points should be carefully located because, on a map, these points become the framework by means of which details are fixed.

12. (a) The latitude of any line is the orthographic projection of that line on a meridian. (b) The departure of a line is its orthographic projection on a parallel.

13. In equation form, latitude and departure are written:

$$\text{latitude} = r \cos \theta, \text{ and}$$
$$\text{departure} = r \sin \theta.$$

14. (a) The latitude for a course with a northerly bearing has a positive sign. (b) The latitude for a course with a southerly bearing has a negative sign. (c) A departure for a course with an easterly bearing has a positive sign. (d) A departure for a course with a westerly bearing has a negative sign.

15. The error of closure is the length of the line joining the start of a survey with the last point of the survey.

16. To get the precision of measurement of the survey of a closed traverse, divide the total error of closure by the total length of the courses.

17. The compass rule states that the correction to be applied to the latitude or departure of any course is to the total error in the sum of the latitudes or departures as the length of the course is to the total length of the traverse.

18. $V = \frac{(A_1 + A_2)}{2} l$ in which A_1 and A_2 represent the respective end areas in square feet, l the distance between the areas in feet, and V the volume in cubic feet.

19. The degree of curve may be defined either as the central angle subtended by a chord of 100 feet or as the central angle subtended by an arc of 100 feet.

20. It is important to know which definition for the degree of curve is being used, because of the difference in length between the arc and the chord subtended by any given degree of curve.

21. Parabolic vertical curves are used on railways, highways, and airport runway profiles when the rate or direction of a grade changes.

22. Two types of vertical photographic coverage are single vertical reconnaissance strip and multiple strip photography.

23. A low oblique aerial photograph does not include the horizon, while a high oblique does include it.

24. A trimetrogon installation consists of three wide-angle cameras (one vertical and a left and a right oblique) whose fields overlap each other so that a photographic strip is made from horizon to horizon across the flight line.

25. The four methods of determining the scale of a photograph in decreasing order of their accuracy are the determination of the relationships of (1) photo to ground, (2) photo to map, (3) photo to object of known dimension, and (4) focal length of camera to altitude of camera.

CHAPTER 10

HYDROGRAPHIC DRAFTING

1. A sextant, a portable instrument used to measure the angle between two objects up to 120°, does not require a stable support and therefore is especially suitable for measuring angles from a boat or ship.

2. An echo sounder, such as the fathometer, has largely replaced the lead-line and the sounding pole for taking soundings.

3. The plot plan shows the proposed construction in relation to the topography of the surrounding area and also indicates elevations throughout the construction area.

4. The methods generally used in estimating the quantities for a dredging project are the vertical cross sections method, the contours method, the equal squares method, and scow measurements by volume and by displacement.

5. (a) The datum for Navy installations for the Atlantic and Gulf coasts is mean low water. (b) For the Pacific coast mean lower low water.

6. (a) Spring tides occur near the time of the full moon and the new moon, at which time the sun and moon act together to produce tides higher and lower than average. (b) Neap tides occur when the moon is in the first or last quarter and it and the sun are opposed to each other.

7. The U. S. Coast and Geodetic Survey publishes five volumes of tide tables annually.

8. (a) A tidal current is the horizontal motion of water resulting from the vertical motion caused by the tide. (b) A flood current is the horizontal motion of water toward the land caused by a rising tide. (c) An ebb current is the horizontal motion away from the land caused by a falling tide.

9. The brief period between flood and ebb current when there is no horizontal motion of the water perceptible is called SLACK water.

10. (a) The direction of the tidal current is called SET. (b) The velocity of the tidal current is called DRIFT.

11. Plotting the control is necessary in order that land and marine features may be held in their true relationship to each other and in their correct geographic position on the surface of the earth.

12. Any inaccuracy in the plotting of control stations will result in errors in the positions of the soundings.

13. Triangulation stations are usually plotted by the *dms.* (meridional differences) and the *dps.* (parallel differences) method.

14. Stations located by a topographic survey are usually placed on the master sheet by transfer with tracing paper from the topographic sheet.

15. Cuts are sextant angles, usually taken from a survey ship, between an object whose position is known and an object whose position is to be determined.

16. The boat sheet is the worksheet used by the hydrographic party in the field for plotting the details of a hydrographic survey as it progresses.

17. The most common method of plotting the positions of soundings on the boat sheet is by means of the three-arm protractor, because soundings are usually located by three-point fixes.

18. The best test that can be applied in the field as to the accuracy of the meter scales is by comparison with a meter bar known to be correct.

19. The elements for the construction of a polyconic projection are contained in U. S. Coast and Geodetic Survey Special Publication No. 5, *Tables for a Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridians and Parallels.*

20. A good construction check for the polyconic projection is a comparison of the long diagonal distance from the northeast

to the southwest corner through the construction center with the corresponding distance from the northwest to the southeast corner.

21. In the use of the Mercator table, a minute of longitude on the Equator is the unit of measurement and is used as an expression for the ratio of any one minute of latitude to any other.

22. The true value of a minute of longitude of any latitude may be found in the U. S. Coast and Geodetic Survey Special Publication No. 5, *Tables for Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridians and Parallels.*

23. Data may be transferred from one projection to another by carefully plotting the geographic coordinates of points on one projection and then locating the same points on the second projection.

CHAPTER 11

ILLUSTRATIVE DRAFTING

1. A poster should be brief and striking in composition and color because it must catch the attention of the passerby.

2. The three principles of composition which apply to every composition are unity, equilibrium or balance, and the center, or order, of interest.

3. In inexact figures, the ideal proportion is 3:5 and 5:8. The ratio which may be substituted is 3:5.

4. The reproduction process to be used will affect the method used to prepare the artwork.

5. The silk screen reproduction process is excellent for small quantities of a poster or placard.

6. The materials needed for silk screen work consist of a frame, which may be made or purchased commercially, and which is hinged to the base; special silk for the screen; material for preparing a stencil; silk screen colors; and a squeegee.

7. The number of colors to be used determines the number of stencils, one stencil to each color, to be prepared for one poster in the silk screen paper stencil method.

8. Artwork to be printed by the silk screen paper stencil method should be designed for stencils printing flat colors.

9. Mimeographing, multilithing, and multigraphing are generally referred to as duplicating methods.
10. Line drawings are made on a mimeograph stencil by cutting away the top surface or coating of the stencil sheet with a stylus.
11. A sheet of thin cellophane may be placed on the stencil and the second line drawn on top of the cellophane.
12. Illustrations to be used in material to be multigraphed must be converted into special curved electrotypes, nickel plates, or rubber plates.
13. The inking mechanism on a multilith machine cannot handle a large enough flow of ink to print large solid areas of ink well.
14. A piece of artwork to be reproduced by ozalid must be prepared on translucent paper.
15. The first step in reproducing artwork in the photo-offset lithography process is photographic.
16. It is possible to make corrections on blueprints of a piece of artwork to be printed by photo-offset lithography because the printing plate itself has not yet been made and certain corrections can still be made on the negative plate.
17. Artwork is prepared for reproduction by letterpress as metal plates, or cuts, by photoengraving, a photographic process very similar to the process used in photo-offset lithography.
18. A signature is a unit, in multiples of 4 pages, which is made by folding one sheet of printing paper.
19. A spread consists of the two facing pages which make a unit in appearance when the book is opened.
20. A bleed illustration is a picture that runs off the page when the publication is trimmed.
21. It is essential that you keep the format of the publication in mind when you prepare illustrations because the artwork will be a failure if it must be reduced so far that it is illegible or if it is the wrong shape to fit in the space available for it in the publication.
22. Training aids may be (1) used to provide the student with an incentive to learning and (2) they can provide the link between the description of a process and the doing of it.
23. The smaller size of slide is 2 inches by 2 inches, and the larger is 3¼ inches by 4 inches.

24. The maximum size for a transparency is 10 inches by 10 inches.
25. Transparencies may be duplicated by photography, the ozalid process, or fluid duplicators.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

DRAFTSMAN (DM)

QUALS CURRENT THROUGH CHANGE 10

General Service Rating

SCOPE

Draftsmen prepare, edit, and file topographical hydrographical, architectural, structural, mechanical, and electrical drawings—plans, sketches, tracings, illustrations, maps, and charts from rough or detailed sketches—notes, and illustrations, using pencil, ink, or colors; trace, copy, compare, modify, and file statistical charts and diagrams from information provided; prepare material estimates and bills of material; make, correct, and file blueprints; operate machines to reproduce drawings; letter and sketch; make computations required of draftsmen; cut, lay out, arrange, and mount photographs, lettering, and sketches to form required patterns, designs, and maps.

Emergency Service Ratings

DRAFTSMEN S (Structural) ---------------------------- DMS
Make architectural and structural drawings of buildings and structures typical of airfields, advanced bases, and shore stations, and drawings of ship and aeronautical structures.

DRAFTSMEN E (Electrical) ---------------------------- DME
Make drawings of electrical circuits, power transmission and distribution systems.

DRAFTSMEN I (Illustrative) -------------------------- DMI
Make posters, illustrations, and drawings to be used for publicity and training aids.

DRAFTSMEN T (Topographic) ------------------------- DMT
Make topographic drawings and maps and hydrographic charts.

DRAFTSMEN M (Mechanical) ---------------------------- DMM

Make drawings of machines, mechanisms, and plumbing, heating, and ventilating systems.

Navy Enlisted Classification Codes

For specific Navy enlisted classification codes included within this rating, see *Manual of Navy Enlisted Classifications*, NavPers 15105 (Revised), codes DM–3700 to DM–3799.

Qualifications for Advancement in Rating

Qualifications for Advancement in Rating	Applicable Rates					
	DM	DMM	DMS	DME	DMT	DMI
100 PRACTICAL FACTORS						
101 OPERATIONAL						
1. Select and use ink and pencil drafting instruments, drawing materials, and equipment	3	3	3	3	3	3
2. Make drawing measurements, divide and subdivide distances, using architect and engineer scales	3	3	3	3	3	3
3. Draw plane geometric constructions applicable to drafting	3	3	3	3	3	3
4. Letter freehand in commercial Gothic style (ink and pencil) as required for reproduction purposes in accordance with JAN & MIL STDS	3	3	3	3	3	3
5. Letter neatly and legibly for illustrative purposes using a reference for construction Old English, Roman, and so forth	2	-----	-----	-----	-----	3
6. Letter neatly and legibly, using lettering devices of the Leroy and Wrico types	3	3	3	3	3	3
7. Read and interpret simple drawings, maps, and charts	3	3	3	3	3	3

Qualifications for Advancement in Rating	Applicable Rates					
	DM	DMM	DMS	DME	DMT	DMI
101 OPERATIONAL—Continued						
8. Trace and revise drawings, maps, and charts (ink and pencil) as directed	3	3	3	3	3	3
9. Prepare graphs and organization charts as directed	3	3	3	3	3	3
10. Make arithmetical computations, using fractions, decimals, square root, ratio and proportion, reciprocals and percentage	3	3	3	3	3	3
11. Make computations of volumes and areas, using formulas and constants applied from handbooks	3	3	3	3	3	3
12. Make conversions of:						
a. Weights and measures	3	3	3	-----	-----	-----
b. Time and distance, courses, and geographic positions	3	-----	-----	-----	3	-----
c. Electric units	3	-----	-----	3	-----	-----
13. Operate reproduction machines of the blueprint or ammonia vapor type, as assigned	3	3	3	3	3	3
14. Use trigonometric and logarithmic tables. Use slide rule to perform multiplication, division, ratio and proportion, square and square root	2	2	2	2	2	-----
15. Use precision measuring instruments such as:						
a. Micrometer and vernier calipers	2	2	-----	-----	-----	-----
b. Meter bar, planimeter, and pantograph	2	-----	-----	-----	2	-----
16. Use tables and data from handbooks and technical publications for drafting purposes	2	2	2	2	2	2

Qualifications for Advancement in Rating	Applicable Rates					
	DM	DMM	DMS	DME	DMT	DMI
101 OPERATIONAL -Continued						
17. Draw freehand sketches from existing objects or dimensions and verbal descriptions	2	2	2	2	2	2
18. Make orthographic projections or pictorial representations for reproduction of:						
a. Machine detail and assembly drawing and plumbing, heating, and ventilating drawings	2	2	-----	-----	-----	-----
b. Architectural and structural drawings	2	-----	2	-----	-----	-----
c. Electrical diagrams and drawings	2	-----	-----	2	-----	-----
d. Topographic plans, profiles, contours, cross sections, maps, and hydrographic charts	2	-----	-----	-----	2	-----
e. Illustrative drawings and posters	2	-----	-----	-----	-----	2
19. Draw pattern developments	2	2	2	-----	-----	-----
20. Plot courses and positions and determine distances on map and chart projections	2	-----	-----	-----	2	-----
21. Make surveying computations for drafting purposes: Reduction of level notes, transit notes, and interpolation for contours	2	-----	-----	-----	2	-----
22. Draw double auxiliary views and perspective projections	1	1	1	1	-----	1
23. Make the following layouts:						
a. Mechanisms such as cams, gears, belts, and pulleys and systems of plumbing, heating, and ventilating	1	1	-----	-----	-----	-----
b. Architectural and structural	1	-----	1	-----	-----	-----

Qualifications for Advancement in Rating	Applicable Rates					
	DM	DMM	DMS	DME	DMT	DMI
101 OPERATIONAL—Continued						
c. Electrical systems and equipment	1			1		
d. Advanced base and airfield	1				1	
e. Illustrative	1					2
24. Construct polyconic and Mercator projections from tables	1				1	
25. Plot and transfer data from one map or chart projection to another such as gnomonic to Mercator	1				1	
26. Make quantity estimates from bills of material and existing drawings	1	1	1	1	1	
27. Make office computations for estimating cut and fill, and horizontal and vertical curves, using handbooks	1				1	
28. Make office computations for estimating latitudes and departures and tides and currents, using handbooks	1				1	
102 MAINTENANCE AND/OR REPAIR						
1. Maintain instruments and equipment used by draftsmen	3	3	3	3	3	3
2. Make minor repairs on instruments and equipment used by draftsmen	2	2	2	2	2	2
103 ADMINISTRATIVE AND/OR CLERICAL						
1. File drawings, tracings, prints, publications, specifications, and drafting data	3	3	3	3	3	3
2. Edit drawings, maps, and charts for accuracy, workmanship, neatness, and conformity to accepted drafting standards	1	1	1	1	1	1
3. Keep records of drafting room operations	1	1	1	1	1	1

Qualifications for Advancement in Rating	Applicable Rates					
	DM	DMM	DMS	DME	DMT	DMI
103 ADMINISTRATIVE AND/OR CLERICAL—Continued						
4. Initiate filing systems, prepare requisitions, and make reports of operations pertaining to a drafting room	C	C	C	C	C	C
5. Supervise and train personnel engaged in drafting operations	C	C	C	C	C	C
6. Organize and administer a drafting room or section	C	C	C	C	C	C
200 EXAMINATION SUBJECTS						
201 OPERATIONAL						
1. Identification and use of drafting instruments, materials, and equipment	3	3	3	3	3	3
2. JAN & MIL STDS for general drawing practice, drawing sizes, and formats	3	3	3	3	3	-----
3. Reading and use of drawing and chart scales	3	3	3	3	3	3
4. Plane geometric constructions applicable to drafting	3	3	3	3	3	3
5. Third angle orthographic projection, single auxiliaries, and sectioning	3	3	3	3	3	3
6. Types of map and chart projections (Mercator, polyconic, lambert conformal, gnomonic, and polar gnomonic)	3	-----	-----	-----	3	-----
7. Fundamental operations of arithmetic; fractions, decimals, square roots, ratio and proportion, reciprocals, geometric progression, and percentages	3	3	3	3	3	3
8. Plane geometry and mensuration	3	3	3	3	3	3

Qualifications for Advancement in Rating	Applicable Rates					
	DM	DMM	DMS	DME	DMT	DMI
201 OPERATIONAL—Continued						
9. Mathematical conversions of:						
a. Weights and measures	3	3	3	-----	-----	-----
b. Time and distance, courses, and geographic positions	3	-----	-----	-----	3	-----
c. Electrical units	3	-----	-----	3	-----	-----
10. Reproduction methods, procedures, and materials of the blueprint or ammonia vapor type processes	3	3	3	3	3	-----
11. Standard drafting conventions (use of symbols from reference handbooks and JAN and MIL STDS) employed in:						
a. Machine, plumbing, heating, and ventilating drafting	3	3	-----	-----	-----	-----
b. Architectural and structural drafting	3	-----	3	-----	-----	-----
c. Electrical drafting	3	-----	-----	3	-----	-----
d. Topographic and hydrographic drafting	3	-----	-----	-----	3	-----
e. Illustration drawing	3	-----	-----	-----	-----	3
12. Isometric and oblique drawings	2	2	2	2	2	2
13. Freehand perspective drawing	2	-----	-----	-----	-----	3
14. Reading scales of precision measuring instruments	2	2	2	2	2	2
15. MIL STDS dimensioning and tolerance	2	2	2	2	2	-----
16. Elements of machining operations, materials, and heat treatment	2	2	-----	-----	-----	-----
17. Elements of plumbing, and heating and ventilating systems (pipe, fittings, equipment, and materials)	2	2	-----	-----	-----	-----

Qualifications for Advancement in Rating	Applicable Rates					
	DM	DMM	DMS	DME	DMT	DMI
201 OPERATIONAL—Continued						
18. Elements of building construction; light frame and masonry foundations, floors, walls, roofs, and building materials	2	-----	2	-----	-----	-----
19. Elements of timber, steel, and concrete structures (materials and methods of assembly)	2	-----	2	-----	-----	-----
20. Elements of simple electrical circuits, equipment, power transmission, and distribution systems	2	-----	-----	2	-----	-----
21. Elements of topographic surveying—leveling and traverse methods as related to drafting	2	-----	-----	-----	2	-----
22. Elements of hydrographic surveying—soundings, positions, and range lines, as related to drafting	2	-----	-----	-----	2	-----
23. Elements of map and chart construction—Mercator, polyconic, lambert conformal, gnomonic, and polar gnomonic	2	-----	-----	-----	2	-----
24. Elements of commercial art—drawing fundamentals, composition, mediums, types of illustration drawings and drawings for reproduction	2	-----	-----	-----	-----	2
25. Elementary trigonometry and algebra	2	2	2	2	2	-----
26. Elementary mechanics—forces and simple machines	1	1	1	1	1	-----
27. Perspective projection	1	1	1	1	1	1
28. Colors and their use in illustration drawing	1	-----	-----	-----	-----	2
29. Nomenclature, drafting conventions, and trade practices peculiar to own specialty	C	C	C	C	C	-----
30. Principles of illustrative layout and design	C	-----	-----	-----	-----	1

Qualifications for Advancement in Rating	Applicable Rates					
	DM	DMM	DMS	DME	DMT	DMI
202 MAINTENANCE AND/OR REPAIR						
1. Maintenance of commonly used drafting instruments and equipment	3	3	3	3	3	3
2. Procedures for obtaining repairs to and replacement of drafting equipment	2	2	2	2	2	2
203 ADMINISTRATIVE AND/OR CLERICAL						
1. Methods and procedures for filing blueprints, drawings, tracings, specifications, and drafting data	3	3	3	3	3	3
2. Factors involved in estimating time required to produce specific drawings	2	2	2	2	2	2
3. Editorial standards of accuracy and workmanship for:						
a. Drawings	1	1	1	1	-----	-----
b. Maps and charts	1	-----	-----	-----	1	-----
c. Illustrations	1	-----	-----	-----	-----	1
4. Space, equipment, and personnel requirements for a typical drafting room or section	C	C	C	C	C	C
5. Organization and administration of a drafting room or section	C	C	C	C	C	C
300 PATH OF ADVANCEMENT TO WARRANT OFFICER AND LIMITED DUTY OFFICER						
Draftsmen advance to CEC Warrant (849) and/or to Limited Duty Officer (570), Civil Engineer Corps.						

APPENDIX III

LIST OF HANDBOOKS AND REFERENCE VOLUMES

Architectural Graphic Standards. RAMSEY, CHARLES GEORGE and SLEEPER, HAROLD REEVE. 4th Ed. 1955. John Wiley & Sons, Inc. New York.

Elementary Surveying. BREED, CHARLES B., and HOSMER, GEORGE L. 8th Ed. 1951. John Wiley & Sons, Inc. New York.

Handbook of Applied Mathematics. GRAZDA, EDWARD E., and BRENNER, MORRIS (based on original work by JANSSON, MARTIN E., HARPER, HERBERT D., and AGNEW, PETER L.) 3rd Ed. 1955. D. Van Nostrand Company, Inc. New York.

Heating, Ventilating, Air Conditioning Guide. (Published annually.) American Society of Heating and Air-Conditioning Engineers, Inc. New York.

Machinery's Handbook. OBERG, ERIK, and JONES, F. D. 15th Ed. 1954. The Industrial Press, New York.

Mechanical Engineers' Handbook. MARKS, LIONEL S. 5th Ed. 1951. McGraw-Hill Book Company, Inc. New York.

National Electric Code Handbook. ABBOTT, ARTHUR L. 8th Ed. 1954. McGraw-Hill Book Company, Inc. New York.

Kent's Mechanical Engineers' Handbook. KENT, WILLIAM. 11th Ed. 1949. John Wiley & Sons, Inc. New York.

Kidder-Parker Architects' and Builders' Handbook. KIDDER, FRANK E. (PARKER, HARRY, Editor-in-Chief). 18th Ed. John Wiley & Sons, Inc. New York.

Steel Construction. 5th Ed. 1955. American Institute of Steel Construction. New York.

Surveying Theory and Practcie. DAVIS, RAYMOND E., FOOTE, FRANCIS S., and RAYNER, W. H. 1953. McGraw-Hill Book Company, Inc. New York.

APPENDIX IV

TABLES ON ELECTRICAL CABLE AND WIRE FOR SHIPBOARD USE

TABLE 1.—*Electric cables for shipboard use*

Cable designation	Types
Cables for non-flexing service:	
SHFA	Single, heat- and flame-resistant, armored.
DHFA	Double, heat- and flame-resistant, armored.
THFA	Triple, heat- and flame-resistant, armored.
FHFA	Four, heat- and flame-resistant, armored.
SHFP	Single, heat- and flame-resistant, propulsion.
SHFR	Single, heat- and flame-resistant, radio.
DHFR	Double, heat- and flame-resistant, radio.
THFR	Triple, heat- and flame-resistant, radio.
SDGA	Single, degaussing, armored.
MDGA	Multiconductor, degaussing, armored.
MDGL	Multiconductor, degaussing, leaded.
MHFA	Multiconductor, heat- and flame-resistant, armored.
TTHFWA	Twisted paid, telephone, heat- and flame-resistant, armored.
PBJX	Pyrometer base lead wire (one iron, one constantine).
PBTX	Pyrometer base lead wire (one copper, one constantine).
TTRSA	Twisted shielded pair, radio, armored.
MCSC	Multiple-conductor, steel core.
DBSP	Double, small-boat, shielded, plain.
TBSP	Triple, small-boat, shielded, plain.
FBSP	Four, small-boat, shielded, plain.
FCSF	Four, combination, special-purpose, flexible.
MCGC	Multiple-conductor, glass-core.
SDU	Single, degaussing, unarmored.
Cables for repeated flexing service:	
SCOP	Single-conductor, oil-resistant, portable.
DCOP	Double-conductor, oil-resistant, portable.
TCOP	Triple-conductor, oil-resistant, portable.
FCOP	Four-conductor, oil-resistant, portable.
MHFF	Multiconductor, heat- and flame-resistant, flexible.

TABLE 1.—*Electric cables for shipboard use*—Continued

Cable designation	Types
TTOP	Twisted-pair, telephone, oil-resistant, portable.
MCOS	Multiple-conductor, oil-resistant, shielded.
MMOP	Multiconductor, microphone, oil-resistant, portable.
SHOF	Single, heat- and oil-resistant, flexible.
DHOF	Double, heat- and oil-resistant, flexible.
Cables for repeated flexing service—*Continued*	
THOF	Triple, heat- and oil-resistant, flexible.
FHOF	Four, heat- and oil-resistant, flexible.
TRF	Tough rubber jacket, flexible.
TRXF	Tough rubber jacket, extra flexible.
TTRS	Twisted shielded-pair, radio, flexible.
CVSF	Combination, aircraft-carrier, special-purpose, flexible.
FCOTP-4	Four-conductor, oil-resistant, thin-walled, portable.
Miscellaneous wires:	
SRI	Single, resin-insulated.
SRIB	Single, resin-insulated, braided.
SHFS	Single, heat- and flame-resistant, switchboard.
MRI	Multiconductor, resin-insulated.

TABLE 2.—*Cables for nonflexing service (permanent installation), heat- and flame-resistant*

[Maximum voltage, 600; maximum total operating temperature, 105 °C.]

Type	Conductors		Over-all diameter (maximum)	General ampere ratings (maximum)				Minimum radius of bend	Estimated weight per foot
				40°C. ambient		50°C. ambient			
	Number	Area (c.m.)	(*Inches*)	Individual	Average	Individual	Average	(*Inches*)	(*Pounds*)
SHFA- 3	1	2,828	0.355	15	....	14	....	2.5	0.068
4	1	4,497	.500	26	....	24	....	3.0	.134
9	1	9,016	.656	53	....	49	....	4.0	.230
14	1	14,340	.684	71	....	65	....	4.5	.262
23	1	22,800	.719	92	....	85	....	4.5	.306
30	1	30,860	.749	113	....	104	....	5.0	.346
40	1	38,910	.774	129	....	119	....	5.0	.385
50	1	49,080	.802	149	....	137	....	5.5	.431
60	1	60,090	.830	170	....	156	....	5.5	.479
75	1	75,780	.865	197	....	181	....	5.5	.548
100	1	99,060	.911	232	....	214	....	6.0	.645
125	1	124,900	.955	269	....	248	....	6.0	.750
150	1	157,600	1.010	314	....	289	....	6.5	.878
200	1	198,700	1.060	361	....	332	....	6.5	1.040
300	1	296,400	1.180	467	....	430	....	7.5	1.400
400	1	413,600	1.340	575	....	530	....	8.5	1.890
500	1	521,600	1.430	671	....	618	....	9.0	2.280
650	1	658,700	1.530	785	....	722	....	10.0	2.770
800	1	829,300	1.650	940	....	865	....	10.5	3.370
DHFA- 3	2	2,828	.530	13	....	12	....	3.5	.143
4	2	4,497	.778	22	....	20	....	5.0	.294
9	2	9,016	.842	44	....	41	....	5.5	.361
14	2	14,340	.922	60	....	55	....	6.0	.451
23	2	22,800	.992	78	....	72	....	6.5	.555
30	2	30,860	1.110	94	....	87	....	7.0	.694
40	2	38,910	1.170	109	....	100	....	7.5	.793
50	2	49,080	1.220	126	....	116	....	8.0	.907
60	2	60,090	1.340	143	....	132	....	8.5	1.080
75	2	75,780	1.470	168	....	155	....	9.5	1.330
100	2	99,060	1.590	199	....	183	....	10.0	1.600
125	2	124,900	1.670	228	....	210	....	11.0	1.850
150	2	157,600	1.850	267	....	246	....	12.0	2.250
200	2	198,700	1.970	308	....	284	....	12.5	2.720
250	2	250,500	2.140	361	....	332	....	13.5	3.280
300	2	296,400	2.280	413	....	380	....	15.0	3.700
400	2	413,600	2.510	492	....	453	....	16.0	4.750
THFA- 3	3	2,828	.560	11	....	10	....	3.5	.171
4	3	4,497	.812	18	....	17	....	5.0	.334
9	3	9,016	.881	39	....	36	....	5.5	.413
14	3	14,340	.968	51	....	47	....	6.0	.527
23	3	22,800	1.040	69	....	64	....	6.5	.659
30	3	30,860	1.170	84	....	77	....	7.5	.855
40	3	38,910	1.230	96	....	88	....	8.0	.997

TABLE 2.—*Cables for nonflexing service (permanent installation), heat- and flame-resistant*—Continued

[Maximum voltage, 600; maximum total operating temperature, 105°C.]

Type	Conductors		Over-all diameter (maximum) (*Inches*)	General ampere ratings (maximum)				Minimum radius of bend (*Inches*)	Estimated weight per foot (*Pounds*)
				40° C. ambient		50° C. ambient			
	Number	Area (c.m.)		Individual	Average	Individual	Average		
THFA-50	3	49,080	1.290	110	------	101	------	8.5	1.130
60	3	60,090	1.420	126	------	116	------	9.0	1.350
75	3	75,780	1.560	148	------	136	------	10.0	1.670
100	3	99,060	1.680	174	------	160	------	11.0	2.000
125	3	124,900	1.780	201	------	185	------	11.5	2.380
150	3	157,600	1.970	235	------	216	------	12.5	2.910
200	3	198,700	2.090	271	------	250	------	13.5	3.490
250	3	250,500	2.280	315	------	290	------	14.5	4.260
300	3	296,400	2.430	348	------	320	------	15.5	4.940
350	3	349,800	2.550	391	------	360	------	16.5	5.740
400	3	413,600	2.670	435	------	400	------	17.0	6.380
FHFA-3	4	2,828	.610	11	------	10	------	4.0	.205
4	4	4,497	.865	18	------	17	------	5.5	.389
SHFS [1]-1	1	953	.125	3	------	3	------	.5	.013
1½	1	1,630	.140	5	------	5	------	.5	.015
2½	1	2,613	.145	9	------	8	------	.5	.019
3 (7)	1	2,828	.155	10	------	9	------	.5	.021
3 (19)	1	3,036	.160	11	------	10	------	.5	.022
4	1	4,497	.195	27	------	25	------	1.0	.034
6	1	6,088	.220	39	------	36	------	1.0	.043
9	1	9,016	.248	54	------	50	------	1.0	.058
14	1	14,340	.276	75	------	69	------	1.5	.079
26	1	26,250	.365	103	------	95	------	2.0	.151
42	1	41,740	.425	134	------	123	------	2.5	.221
66	1	66,370	.505	168	------	155	------	3.0	.313
100	1	99,060	.543	212	------	195	------	3.5	.423
MHFA-7	7	2,828	.859	12	8	9	6	5.5	.383
10	10	2,828	1.040	12	8	9	6	6.5	.516
14	14	2,828	1.120	12	8	9	6	7.5	.634
19	19	2,828	1.210	12	8	9	6	8.0	.764
22	22	2,828	1.330	12	6	9	5	8.5	.893
26	26	2,828	1.420	12	6	9	5	9.0	1.010
30	30	2,828	1.460	12	6	9	5	9.5	1.090
37	37	2,828	1.570	12	6	9	5	10.0	1.290
44	44	2,828	1.730	12	5	9	4	11.0	1.500

[1] Switchboard and panel wiring.

TABLE 3.—*Cables for repeated flexing service*

[Maximum voltage, 600; maximum total operating temperature, 75°C.]

Type	Conductors		Over-all diameter (Maximum)	Ampere ratings (maximum)				Weight per foot
				40°C. ambient		50°C. ambient		
	Number	Area (c.m.)		Individual	Average	Individual	Average	
Oil resistant:			*Inches*					*Pounds*
SCOP- 23	1	22,910	0.420	52		44		0.148
60	1	61,260	.590	99		84		.332
150	1	153,100	.868	200		169		.747
200	1	199,100	.980	244		206		.938
250	1	252,700	1.090	286		242		1.280
814	1	812,700	1.670	878		573		3.210
DCOP-½ (T_1)[1]	2	525	.250		Telephone cord			.026
(T_2)[1]	2	525	.190		do			.020
1[2]	2	953	.250	3		2		.030
1½[2]	2	1,608	.310	5		3		.057
2[2]	2	2,613	.340	12		8		.065
2½[2]	2	2,613	.305 x .185	12		8		.050
3	2	2,613	.440	12		8		.099
4	2	4,121	.460	16		11		.115
6	2	6,533	.510	22		16		.146
9	2	9,045	.530	29		20		.167
14	2	14,070	.706	40		29		.285
23	2	22,910	.858	58		41		.402
30	2	30,550	.960	72		49		.606
83	2	84,230	1.450	170		97		1.32
250	2	252,700	2.10	360		250		2.73
400	2	413,500	2.50	540		350		4.40
672	2	671,000	3.00	760		520		6.59
TCOP-½ (T_1)[1]	3	525	.250		Telephone cord			.026
(T_2)[1]	3	525	.190		do			.033
2[2]	3	1,608	.325	7		5		.049
3	3	2,613	.375	10		6		.092
4	3	4,121	.460	14		9		.133
6	3	6,533	.520	19		12		.174
9	3	9,045	.540	25		16		.196
23	3	22,910	.903	48		31		.518
42	3	42,110	1.250	75		43		.958
150	3	153,100	1.820	190		122		2.40
250	3	252,700	2.240	278		175		3.76
400	3	413,500	2.800	400		250		5.95
FCOP- 3	4	2,613	.460	8		5		.127
4	4	4,121	.520	13		11		.162
9	4	9,045	.640	21		18		.273
133	4	153,100	2.00	142		120		2.781
TTOP- 3[1] [2]	3	953	.480		Telephone cable.			.111
5[1] [2]	5	953	.540					.151

TABLE 3.—*Cables for repeated flexing service*—Continued

[Maximum voltage, 600; maximum total operating temperature, 75°C.]

Type	Conductors		Over-all diameter (Maximum)	Ampere ratings (maximum)				Weight per foot
				40°C. ambient		50°C. ambient		
	Number	Area (c.m.)		Individual	Average	Individual	Average	
			Inches					*Pounds*
10[1, 3]	10	953	0.675					0.263
15[1, 3]	15	953	.830					.374
20[1, 3]	20	953	.940					.470
25[1, 3]	25	953	1.04					.568
30[1, 3]	30	953	1.12					.626
40[1, 3]	40	953	1.27					.811
50[1, 3]	50	953	1.45					1.031
60[1, 3]	60	953	1.55					1.217
MCOS-2	2	1,640	.460	5		4		.126
4	4	1,640	.510	5	3	4	2	.162
6[4]	6	825	.465	2.5	1	2	1	.102
7	7	1,610	.595	5	2.5	4	1.5	.230
Welding:[4]								
TRF- 17	1	17,000	.420	45		38		.125
26	1	26,000	.480	59		50		.192
42	1	42,000	.560	82		69		.236
53	1	53,000	.620	96		81		.296
66	1	66,000	.660	111		94		.368
84	1	84,000	.720	130		110		.432
105	1	105,000	.760	143		121		.510
133	1	133,000	.810	167		141		.618
168	1	168,000	.860	201		170		.704
212	1	212,000	.920	234		198		.870
TRXF- 84[2, 4]	1	84,000	.600	130		110		.360
105[2, 4]	1	105,000	.680	143		121		.460
133[2, 4]	1	133,000	.750	167		141		.567
168[2, 4]	1	168,000	.830	201		170		.709
212[2, 4]	1	212,000	.900	234		198		.883
Heat- and flame-resistant:								
MHFF- 2	2	2,613	.460	8	7	6	5	.107
4	4	2,613	.520	8	6	6	5	.152
7	7	2,613	.627	8	5	6	4	.197
10	10	2,613	.795	8	5	6	4	.300
14	14	2,613	.844	8	5	6	4	.386
19	19	2,613	.995	8	5	6	4	.502
22	22	2,613	1.070	8	4	6	3	.640
26	26	2,613	1.160	8	4	6	3	.718
30	30	2,613	1.190	8	4	6	3	.793
37	37	2,613	1.290	8	4	6	3	.914
44	44	2,613	1.420	8	3	6	2	1.13

[1] Maximum voltage, 60.
[2] Maximum voltage, 300.
[3] Twisted pairs.
[4] The current ratings are for continuous duty and may be exceeded for welding applications.

Table 4.—*Synthetic resin-insulated cables and cords*

[Maximum voltage, 600; maximum operating total temperature, 60°C.]

Type	Conductors		Maximum over-all diameter (*inches*)	Ampere ratings (max.)		Minimum radius of bend	Estimated weight per foot (*pounds*)
	Number	Area (c.m.)		40°C. ambient	50°C. ambient		
SRI- 3/5 (1) [1]	1	642	0.060	3	2	....	0.003
1 (19) [1]	1	953	.073	4	3	....	.005
1 (1) [1]	1	1,022	.070	4	3	....	.005
1½ [1]	1	1,608	.077	5	3	....	.007
1½ (41) [1]	1	1,630	.090	5	4	....	.008
2½ (1) [1]	1	2,624	.090	6	5	....	.010
2½ (26) [1]	1	2,613	.102	7	5	....	.011
3 (7) [1]	1	2,828	.102	7	5	....	.013
3 (19) [1]	1	3,036	.105	7	5	....	.014
4 (1)	1	4,107	.105	9	6	....	.016
4 (41)	1	4,121	.125	10	7	....	.017
4 (7)	1	4,497	.125	10	7	....	.018
6 (7)	1	6,512	.150	13	9	....	.026
6 (19)	1	6,088	.150	13	9	....	.026
6 (1)	1	6,530	.130	13	9	....	.026
6 (65)	1	6,533	.160	13	10	....	.028
8 (1)	1	8,234	.150	15	11	....	.033
9 (7)	1	9,016	.178	17	12	....	.038
9 (90)	1	9,045	.190	17	12	....	.040
13 (1)	1	13,090	.184	20	15	....	.049
14 (7)	1	14,340	.206	23	16	....	.057
21 (1)	1	20,820	.214	28	20	....	.075
23 (7)	1	22,800	.241	31	22	....	.089
40 (19)	1	38,910	.306	46	33	....	.146
60 (37)	1	60,090	.372	63	45	....	.217
75 (37)	1	75,780	.407	74	53	....	.270
100 (61)	1	99,060	.453	89	64	....	.345
SRIB- 3/5 [1, 2]	1	642	.100	4	4	0.5	.005
1 (1) [1, 2]	1	1,022	.108	6	5	.5	.007
1 (19) [1, 2]	1	953	.110	3	5	.5	.007
1½ (1) [1, 2]	1	1,624	.115	7	6	.5	.010
1½ (41) [1, 2]	1	1,630	.125	8	6	.5	.012
2½ (1) [1, 2]	1	2,583	.125	10	8	.5	.014
2½ (26) [1, 2]	1	2,613	.137	10	9	.5	.015
3 (7) [2]	1	2,828	.137	10	9	.5	.017
3 (19) [2]	1	3,036	.140	11	9	.5	.018
4 [2]	1	4,497	.165	15	13	1.0	.027
6 [2]	1	6,512	.190	20	16	1.0	.036
9 [2]	1	9,016	.218	25	21	1.0	.048
14 [2]	1	14,340	.246	33	28	1.5	.067
23 [2]	1	22,800	.281	44	37	2.0	.098

[1] Maximum voltage, 300.
[2] Maximum total operating temperature, 75° C.

TABLE 5.—*Standard annealed solid copper wire*

[American wire gage—B. & S.]

Gage number	Diameter (mils)	Cross section		Ohms per 1,000 ft.		Ohms per mile	Pounds per 1,000 ft.
		Circular mils	Square inches	25°C. (=77°F.)	65°C. (=149°F.)	25°C. (=77°F.)	
0000	460.0	212,000.0	0.166	0.0500	0.0577	0.264	641.0
000	410.0	168,000.0	.132	.0630	.0727	.333	508.0
00	365.0	133,000.0	.105	.0795	.0917	.420	403.0
0	325.0	106,000.0	.0829	.100	.116	.528	319.0
1	289.0	83,700.0	.0657	.126	.146	.665	253.0
2	258.0	66,400.0	.0521	.159	.184	.839	201.0
3	229.0	52,600.0	.0413	.201	.232	1.061	159.0
4	204.0	41,700.0	.0328	.253	.292	1.335	126.0
5	182.0	33,100.0	.0260	.319	.369	1.685	100.0
6	162.0	26,300.0	.0206	.403	.465	2.13	79.5
7	144.0	20,800.0	.0164	.508	.586	2.68	63.0
8	128.0	16,500.0	.0130	.641	.739	3.38	50.0
9	114.0	13,100.0	.0103	.808	.932	4.27	39.6
10	102.0	10,400.0	.00815	1.02	1.18	5.38	31.4
11	91.0	8,230.0	.00647	1.28	1.48	6.75	24.9
12	81.0	6,530.0	.00513	1.62	1.87	8.55	19.8
13	72.0	5,180.0	.00407	2.04	2.36	10.77	15.7
14	64.0	4,110.0	.00323	2.58	2.97	13.62	12.4
15	57.0	3,260.0	.00256	3.25	3.75	17.16	9.86
16	51.0	2,580.0	.00203	4.09	4.73	21.6	7.82
17	45.0	2,050.0	.00161	5.16	5.96	27.2	6.20
18	40.0	1,620.0	.00128	6.51	7.51	34.4	4.92
19	36.0	1,290.0	.00101	8.21	9.48	43.3	3.90
20	32.0	1,020.0	.000802	10.4	11.9	54.9	3.09
21	28.5	810.0	.000636	13.1	15.1	69.1	2.45
22	25.3	642.0	.000505	16.5	19.0	87.1	1.94
23	22.6	509.0	.000400	20.8	24.0	109.8	1.54
24	20.1	404.0	.000317	26.2	30.2	138.3	1.22
25	17.9	320.0	.000252	33.0	38.1	174.1	0.970
26	15.9	254.0	.000200	41.6	48.0	220.0	0.769
27	14.2	202.0	.000158	52.5	60.6	277.0	0.610
28	12.6	160.0	.000126	66.2	76.4	350.0	0.484
29	11.3	127.0	.0000995	83.4	96.3	440.0	0.384
30	10.0	101.0	.0000789	105.0	121.0	554.0	0.304
31	8.9	79.7	.0000626	133.0	153.0	702.0	0.241
32	8.0	63.2	.0000496	167.0	193.0	882.0	0.191
33	7.1	50.1	.0000394	211.0	243.0	1,114.0	0.152
34	6.3	39.8	.0000312	266.0	307.0	1,404.0	0.120
35	5.6	31.5	.0000248	335.0	387.0	1,769.0	0.0954
36	5.0	25.0	.0000196	423.0	488.0	2,230.0	0.0757
37	4.5	19.8	.0000156	533.0	616.0	2,810.0	0.0600
38	4.0	15.7	.0000123	673.0	776.0	3,550.0	0.0476
39	3.5	12.5	.0000098	848.0	979.0	4,480.0	0.0377
40	3.1	9.9	.0000078	1,070.0	1,230.0	5,650.0	0.0299

APPENDIX V

MERCATOR PROJECTION TABLES

MERCATOR PROJECTION TABLE.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	0° Meridional distance.	0° Difference.	1° Meridional distance.	1° Difference.	2° Meridional distance.	2° Difference.	3° Meridional distance.	3° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	0.000	0.993	59.596	0.994	119.210	0.994	178.862	0.994	0
1	0.993	993	60.590	993	120.204	994	179.856	995	1
2	1.986	994	61.583	993	121.198	994	180.851	994	2
3	2.980	993	62.576	994	122.192	994	181.845	995	3
4	3.973	993	63.570	993	123.186	994	182.840	994	4
5	4.966	993	64.563	993	124.180	994	183.834	995	5
6	5.959	993	65.556	994	125.174	994	184.829	995	6
7	6.952	994	66.550	993	126.168	994	185.824	994	7
8	7.946	993	67.543	994	127.162	993	186.818	995	8
9	8.939	993	68.537	993	128.155	994	187.813	995	9
10	9.932	0.993	69.530	0.993	129.149	0.994	188.808	0.994	10
11	10.925	993	70.523	994	130.143	994	189.802	995	11
12	11.918	994	71.517	993	131.137	994	190.797	995	12
13	12.912	993	72.510	994	132.131	994	191.792	995	13
14	13.905	993	73.504	993	133.125	994	192.787	995	14
15	14.898	993	74.497	994	134.119	994	193.782	995	15
16	15.891	993	75.491	993	135.113	994	194.777	995	16
17	16.884	994	76.484	993	136.107	994	195.772	995	17
18	17.878	993	77.477	994	137.101	994	196.767	995	18
19	18.871	993	78.471	993	138.095	994	197.762	995	19
20	19.864	0.993	79.464	0.994	139.089	0.994	198.757	0.995	20
21	20.857	994	80.458	993	140.083	994	199.752	995	21
22	21.851	993	81.451	994	141.077	995	200.747	995	22
23	22.844	993	82.445	993	142.072	994	201.742	995	23
24	23.837	994	83.438	994	143.066	994	202.737	995	24
25	24.831	993	84.432	993	144.060	994	203.732	995	25
26	25.824	993	85.425	994	145.054	994	204.727	995	26
27	26.817	993	86.419	994	146.048	994	205.722	995	27
28	27.810	994	87.413	993	147.042	994	206.717	995	28
29	28.804	993	88.406	994	148.036	994	207.712	995	29
30	29.797	0.993	89.400	0.993	149.030	0.994	208.707	0.995	30
31	30.790	993	90.393	994	150.024	995	209.702	995	31
32	31.783	994	91.387	993	151.019	994	210.697	995	32
33	32.777	993	92.380	994	152.013	994	211.692	995	33
34	33.770	993	93.374	994	153.007	994	212.687	995	34
35	34.763	994	94.368	993	154.001	995	213.682	995	35
36	35.757	993	95.361	994	154.996	994	214.677	996	36
37	36.750	993	96.355	993	155.990	994	215.673	995	37
38	37.743	993	97.348	994	156.984	994	216.668	995	38
39	38.736	994	98.342	994	157.978	995	217.663	995	39
40	39.730	0.993	99.336	0.993	158.973	0.994	218.658	0.996	40
41	40.723	993	100.329	994	159.967	994	219.654	995	41
42	41.716	994	101.323	993	160.961	995	220.649	995	42
43	42.710	993	102.316	994	161.956	994	221.644	996	43
44	43.703	993	103.310	994	162.950	994	222.640	995	44
45	44.696	993	104.304	994	163.944	995	223.635	996	45
46	45.689	994	105.298	993	164.939	994	224.631	995	46
47	46.683	993	106.291	994	165.933	995	225.626	996	47
48	47.676	993	107.285	994	166.928	994	226.622	995	48
49	48.669	994	108.279	994	167.922	995	227.617	996	49
50	49.663	0.993	109.273	0.993	168.917	0.994	228.613	0.995	50
51	50.656	993	110.266	994	169.911	994	229.608	995	51
52	51.649	994	111.260	994	170.905	995	230.603	996	52
53	52.643	993	112.254	993	171.900	994	231.599	995	53
54	53.636	993	113.247	994	172.894	995	232.594	996	54
55	54.629	994	114.241	994	173.889	994	233.590	995	55
56	55.623	993	115.235	994	174.883	995	234.585	996	56
57	56.616	993	116.229	994	175.878	994	235.581	996	57
58	57.609	994	117.223	993	176.872	995	236.577	995	58
59	58.603	0.993	118.216	0.994	177.867	0.995	237.572	0.996	59
60	59.596		119.210		178.862		238.568		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$]

Minutes.	4° Meridional distance.	4° Difference.	5° Meridional distance.	5° Difference.	6° Meridional distance.	6° Difference.	7° Meridional distance.	7° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	238.568	0.996	298.348	0.997	358.222	0.998	418.206	1.001	0
1	239.564	995	299.345	997	359.220	999	419.207	001	1
2	240.559	996	300.342	998	360.219	999	420.208	001	2
3	241.555	996	301.340	997	361.218	999	421.209	000	3
4	242.551	996	302.337	997	362.217	999	422.209	001	4
5	243.547	996	303.334	997	363.216	999	423.210	001	5
6	244.543	995	304.331	997	364.215	998	424.211	001	6
7	245.538	996	305.328	998	365.213	999	425.212	001	7
8	246.534	996	306.326	997	366.212	0.999	426.213	001	8
9	247.530	996	307.323	997	367.211	1.000	427.214	002	9
10	248.526	0.996	308.320	0.998	368.211	0.999	428.216	1.001	10
11	249.522	996	309.318	997	369.210	999	429.217	001	11
12	250.518	996	310.315	997	370.209	999	430.218	001	12
13	251.514	996	311.312	998	371.208	999	431.219	001	13
14	252.510	996	312.310	997	372.207	0.999	432.220	002	14
15	253.506	996	313.307	998	373.206	1.000	433.222	001	15
16	254.502	996	314.305	997	374.206	0.999	434.223	001	16
17	255.498	996	315.302	998	375.205	0.999	435.224	002	17
18	256.494	996	316.300	998	376.204	1.000	436.226	001	18
19	257.490	996	317.298	997	377.204	0.999	437.227	002	19
20	258.486	0.996	318.295	0.998	378.203	1.000	438.229	1.001	20
21	259.482	996	319.293	998	379.203	0.999	439.230	002	21
22	260.478	996	320.291	997	380.202	1.000	440.232	002	22
23	261.474	996	321.288	998	381.202	0.999	441.234	001	23
24	262.470	997	322.286	998	382.201	1.000	442.235	002	24
25	263.467	996	323.284	997	383.201	0.999	443.237	002	25
26	264.463	996	324.281	998	384.200	1.000	444.239	002	26
27	265.459	996	325.279	998	385.200	1.000	445.241	001	27
28	266.455	996	326.277	998	386.200	0.999	446.242	002	28
29	267.451	997	327.275	998	387.199	0.999	447.244	002	29
30	268.448	0.996	328.273	0.997	388.198	1.000	448.246	1.002	30
31	269.444	996	329.270	998	389.198	000	449.248	002	31
32	270.440	997	330.268	998	390.198	000	450.250	002	32
33	271.437	996	331.266	998	391.198	000	451.252	002	33
34	272.433	997	332.264	998	392.198	000	452.254	002	34
35	273.430	996	333.262	998	393.198	000	453.256	002	35
36	274.426	997	334.260	998	394.198	000	454.258	002	36
37	275.423	996	335.258	998	395.198	000	455.260	002	37
38	276.419	997	336.256	998	396.198	000	456.262	002	38
39	277.416	996	337.254	999	397.198	000	457.264	003	39
40	278.412	0.997	338.253	0.998	398.198	1.000	458.267	1.002	40
41	279.409	997	339.251	998	399.198	000	459.269	003	41
42	280.406	996	340.249	998	400.198	000	460.272	002	42
43	281.402	997	341.247	998	401.198	000	461.274	003	43
44	282.399	997	342.245	999	402.198	000	462.277	002	44
45	283.396	996	343.244	998	403.198	001	463.279	003	45
46	284.392	997	344.242	998	404.199	000	464.282	002	46
47	285.389	997	345.240	999	405.199	000	465.284	003	47
48	286.386	997	346.239	998	406.199	001	466.287	002	48
49	287.383	997	347.237	999	407.200	000	467.289	003	49
50	288.380	0.996	348.236	0.998	408.200	1.001	468.292	1.003	50
51	289.376	997	349.234	999	409.201	000	469.295	002	51
52	290.373	997	350.233	998	410.201	001	470.297	003	52
53	291.370	997	351.231	999	411.202	000	471.300	003	53
54	292.367	996	352.230	998	412.202	001	472.303	003	54
55	293.363	997	353.228	999	413.203	000	473.306	003	55
56	294.360	997	354.227	999	414.203	001	474.309	003	56
57	295.357	997	355.226	998	415.204	001	475.312	002	57
58	296.354	997	356.224	999	416.205	001	476.314	003	58
59	297.351	0.997	357.223	0.999	417.206	1.000	477.317	1.004	59
60	298.348		358.222		418.206		478.321		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	8° Meridional distance.	8° Difference.	9° Meridional distance.	9° Difference.	10° Meridional distance.	10° Difference.	11° Meridional distance.	11° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	478.321	1.003	538.585	1.006	599.019	1.009	659.641	1.012	0
1	479.324	003	539.591	006	600.028	009	660.653	012	1
2	480.327	003	540.597	006	601.037	009	661.665	013	2
3	481.330	003	541.603	006	602.046	008	662.678	012	3
4	482.333	004	542.609	006	603.054	009	663.690	012	4
5	483.337	003	543.615	006	604.063	009	664.702	013	5
6	484.340	003	544.621	006	605.072	009	665.715	012	6
7	485.343	004	545.627	006	606.081	010	666.727	013	7
8	486.347	003	546.633	006	607.091	009	667.740	012	8
9	487.350	004	547.639	007	608.100	009	668.752	013	9
10	488.354	1.003	548.646	1.006	609.109	1.009	669.765	1.013	10
11	489.357	004	549.652	006	610.118	010	670.778	012	11
12	490.361	004	550.658	006	611.128	009	671.790	013	12
13	491.365	004	551.664	007	612.137	009	672.803	013	13
14	492.369	003	552.671	006	613.146	010	673.816	013	14
15	493.372	004	553.677	007	614.156	010	674.829	013	15
16	494.376	004	554.684	006	615.166	009	675.842	013	16
17	495.380	004	555.690	007	616.175	010	676.855	013	17
18	496.384	004	556.697	006	617.185	010	677.868	013	18
19	497.388	004	557.703	007	618.195	009	678.881	013	19
20	498.392	1.004	558.710	1.007	619.204	1.010	679.894	1.013	20
21	499.396	004	559.717	007	620.214	010	680.907	013	21
22	500.400	004	560.724	007	621.224	010	681.920	014	22
23	501.404	004	561.731	006	622.234	010	682.934	013	23
24	502.408	004	562.737	007	623.244	010	683.947	014	24
25	503.412	004	563.744	007	624.254	010	684.961	013	25
26	504.416	004	564.751	007	625.264	011	685.974	014	26
27	505.420	004	565.758	008	626.275	010	686.988	014	27
28	506.424	005	566.766	007	627.285	010	688.002	013	28
29	507.429	004	567.773	007	628.295	010	689.015	014	29
30	508.433	1.004	568.780	1.007	629.305	1.011	690.029	1.014	30
31	509.437	005	569.787	008	630.316	010	691.043	014	31
32	510.442	004	570.795	007	631.326	011	692.057	014	32
33	511.446	005	571.802	007	632.337	010	693.071	014	33
34	512.451	004	572.809	008	633.347	011	694.085	014	34
35	513.455	005	573.817	007	634.358	011	695.099	014	35
36	514.460	005	574.824	008	635.369	010	696.113	015	36
37	515.465	004	575.832	007	636.379	011	697.128	014	37
38	516.469	005	576.839	008	637.390	011	698.142	014	38
39	517.474	005	577.847	008	638.401	011	699.156	015	39
40	518.479	1.005	578.855	1.007	639.412	1.011	700.171	1.014	40
41	519.484	005	579.862	008	640.423	011	701.185	015	41
42	520.489	005	580.870	008	641.434	011	702.200	015	42
43	521.494	005	581.878	008	642.445	011	703.215	014	43
44	522.499	005	582.886	008	643.456	011	704.229	015	44
45	523.504	005	583.894	008	644.467	011	705.244	015	45
46	524.509	005	584.902	008	645.478	011	706.259	015	46
47	525.514	005	585.910	008	646.489	011	707.274	015	47
48	526.519	006	586.918	008	647.500	012	708.289	015	48
49	527.525	005	587.926	008	648.512	011	709.304	015	49
50	528.530	1.005	588.934	1.008	649.523	1.012	710.319	1.015	50
51	529.535	005	589.942	009	650.535	011	711.334	015	51
52	530.540	006	590.951	008	651.546	012	712.349	015	52
53	531.546	005	591.959	009	652.558	012	713.364	015	53
54	532.551	006	592.968	008	653.570	011	714.379	016	54
55	533.557	006	593.976	009	654.581	012	715.395	015	55
56	534.563	005	594.985	008	655.593	012	716.410	015	56
57	535.568	006	595.993	009	656.605	012	717.425	016	57
58	536.574	006	597.002	008	657.617	012	718.441	016	58
59	537.580	1.005	598.010	1.009	658.629	1.012	719.457	1.015	59
60	538.585		599.019		659.641		720.472		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{293}$.]

Minutes.	12° Meridional distance.	12° Difference.	13° Meridional distance.	13° Difference.	14° Meridional distance.	14° Difference.	15° Meridional distance.	15° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	720.472	1.016	781.532	1.020	842.842	1.024	904.422	1.029	0
1	721.488	016	782.552	020	843.866	024	905.451	029	1
2	722.504	016	783.572	020	844.890	025	906.480	029	2
3	723.520	015	784.592	020	845.915	024	907.509	029	3
4	724.535	016	785.612	020	846.939	024	908.538	029	4
5	725.551	016	786.632	020	847.963	025	909.567	029	5
6	726.567	017	787.652	020	848.988	024	910.596	030	6
7	727.584	016	788.672	020	850.012	025	911.626	029	7
8	728.600	016	789.692	020	851.037	024	912.655	029	8
9	729.616	016	790.712	021	852.061	025	913.684	030	9
10	730.632	1.017	791.733	1.020	853.086	1.025	914.714	1.029	10
11	731.649	016	792.753	020	854.111	025	915.743	030	11
12	732.665	017	793.773	021	855.136	025	916.773	030	12
13	733.682	016	794.794	020	856.161	025	917.803	029	13
14	734.698	017	795.814	021	857.186	025	918.832	030	14
15	735.715	017	796.835	021	858.211	025	919.862	030	15
16	736.732	017	797.856	021	859.236	026	920.892	030	16
17	737.749	016	798.877	021	860.262	025	921.922	031	17
18	738.765	017	799.898	021	861.287	025	922.953	030	18
19	739.782	017	800.919	021	862.312	025	923.983	030	19
20	740.799	1.017	801.940	1.021	863.337	1.026	925.013	1.031	20
21	741.816	017	802.961	021	864.363	026	926.044	030	21
22	742.833	017	803.982	021	865.389	026	927.074	031	22
23	743.850	018	805.003	022	866.415	025	928.105	030	23
24	744.868	017	806.025	021	867.440	026	929.135	031	24
25	745.885	017	807.046	022	868.466	026	930.166	031	25
26	746.902	017	808.068	021	869.492	026	931.197	031	26
27	747.919	018	809.089	022	870.518	026	932.228	031	27
28	748.937	017	810.111	022	871.544	027	933.259	031	28
29	749.954	018	811.133	022	872.571	026	934.290	031	29
30	750.972	1.018	812.155	1.022	873.597	1.026	935.321	1.031	30
31	751.990	017	813.177	022	874.623	026	936.352	032	31
32	753.007	018	814.199	022	875.649	027	937.384	031	32
33	754.025	018	815.221	022	876.676	026	938.415	032	33
34	755.043	018	816.243	022	877.702	027	939.447	031	34
35	756.061	018	817.265	022	878.729	027	940.478	032	35
36	757.079	018	818.287	022	879.756	026	941.510	032	36
37	758.097	018	819.309	023	880.782	027	942.542	031	37
38	759.115	019	820.332	022	881.809	027	943.573	032	38
39	760.134	018	821.354	023	882.836	027	944.605	032	39
40	761.152	1.018	822.377	1.022	883.863	1.028	945.637	1.032	40
41	762.170	019	823.399	023	884.891	027	946.669	033	41
42	763.189	018	824.422	022	885.918	028	947.702	032	42
43	764.207	019	825.444	023	886.946	027	948.734	032	43
44	765.226	018	826.467	023	887.973	028	949.766	033	44
45	766.244	019	827.490	023	889.001	027	950.799	033	45
46	767.263	019	828.513	023	890.028	028	951.832	032	46
47	768.282	019	829.536	023	891.056	028	952.864	032	47
48	769.301	019	830.559	023	892.084	028	953.896	033	48
49	770.320	019	831.582	023	893.112	028	954.929	033	49
50	771.339	1.019	832.605	1.024	894.140	1.028	955.962	1.033	50
51	772.358	019	833.629	023	895.168	028	956.995	033	51
52	773.377	019	834.652	024	896.196	028	958.028	033	52
53	774.396	019	835.676	023	897.224	028	959.061	034	53
54	775.415	019	836.699	024	898.252	028	960.095	033	54
55	776.434	020	837.723	024	899.280	028	961.128	033	55
56	777.454	019	838.747	024	900.308	029	962.161	034	56
57	778.473	020	839.771	023	901.337	028	963.195	033	57
58	779.493	020	840.794	024	902.365	029	964.228	034	58
59	780.513	1.019	841.818	1.024	903.394	1.028	965.262	1.034	59
60	781.532		842.842		904.422		966.296		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$]

Minutes.	16° Meridional distance.	16° Difference.	17° Meridional distance.	17° Difference.	18° Meridional distance.	18° Difference.	19° Meridional distance.	19° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	966.296	1.034	1028.483	1.039	1091.007	1.045	1153.891	1.052	0
1	967.330	034	29.522	039	92.052	046	54.943	051	1
2	968.364	034	30.561	039	93.098	045	55.994	052	2
3	969.398	034	31.600	040	94.143	045	57.046	051	3
4	970.432	034	32.640	040	95.188	046	58.097	052	4
5	971.466	034	33.680	039	96.234	045	59.149	052	5
6	972.500	034	34.719	040	97.279	046	60.201	052	6
7	973.534	034	35.759	040	98.325	045	61.253	052	7
8	974.568	035	36.799	040	1099.370	046	62.305	052	8
9	975.603	035	37.839	040	1100.416	046	63.357	052	9
10	976.638	1.035	1038.879	1.041	1101.462	1.046	1164.409	1.052	10
11	977.673	034	39.920	040	02.508	046	65.461	053	11
12	978.707	035	40.960	040	03.554	047	66.514	052	12
13	979.742	035	42.000	041	04.601	046	67.566	053	13
14	980.777	035	43.041	041	05.647	046	68.619	053	14
15	981.812	035	44.082	040	06.693	047	69.672	052	15
16	982.847	035	45.122	041	07.740	047	70.724	053	16
17	983.882	036	46.163	041	08.787	046	71.777	053	17
18	984.918	035	47.204	041	09.833	047	72.830	054	18
19	985.953	035	48.245	041	10.880	047	73.884	053	19
20	986.988	1.036	1049.286	1.041	1111.927	1.047	1174.937	1.053	20
21	988.024	036	50.327	041	12.974	047	75.990	054	21
22	989.060	035	51.368	041	14.021	048	77.044	053	22
23	990.095	036	52.409	042	15.069	047	78.097	054	23
24	991.131	036	53.451	042	16.116	047	79.151	054	24
25	992.167	036	54.493	041	17.163	048	80.205	054	25
26	993.203	036	55.534	042	18.211	048	81.259	054	26
27	994.239	037	56.576	042	19.259	048	82.313	054	27
28	995.276	036	57.618	042	20.307	047	83.367	054	28
29	996.312	036	58.660	042	21.354	048	84.421	055	29
30	997.348	1.037	1059.702	1.042	1122.402	1.049	1185.476	1.054	30
31	998.385	036	60.744	042	23.451	048	86.530	055	31
32	999.421	037	61.786	042	24.499	048	87.585	055	32
33	1000.458	037	62.828	042	25.547	048	88.640	055	33
34	01.495	037	63.870	043	26.595	049	89.695	055	34
35	02.532	037	64.913	043	27.644	049	90.750	055	35
36	03.569	037	65.956	042	28.693	048	91.805	055	36
37	04.606	037	66.998	043	29.741	049	92.860	055	37
38	05.643	037	68.041	043	30.790	049	93.915	056	38
39	06.680	038	69.084	043	31.839	049	94.971	055	39
40	1007.718	1.037	1070.127	1.043	1132.888	1.049	1196.026	1.056	40
41	08.755	038	71.170	043	33.937	050	97.082	055	41
42	09.793	037	72.213	044	34.987	049	98.137	056	42
43	10.830	038	73.257	043	36.036	050	1199.193	056	43
44	11.878	038	74.300	043	37.086	049	1200.249	056	44
45	12.906	037	75.343	044	38.135	050	01.305	056	45
46	13.943	038	76.387	044	39.185	050	02.361	056	46
47	14.981	038	77.431	044	40.235	050	03.417	057	47
48	16.019	039	78.475	043	41.285	050	04.474	056	48
49	17.058	038	79.518	044	42.335	050	05.530	057	49
50	1018.096	1.038	1080.562	1.045	1143.385	1.050	1206.587	1.056	50
51	19.134	038	81.607	044	44.435	050	07.643	057	51
52	20.172	038	82.651	044	45.485	051	08.700	057	52
53	21.210	039	83.695	044	46.536	050	09.757	057	53
54	22.249	039	84.739	045	47.586	051	10.814	057	54
55	23.288	039	85.784	044	48.637	051	11.871	058	55
56	24.327	039	86.828	045	49.688	050	12.929	057	56
57	25.366	039	87.873	045	50.738	051	13.986	058	57
58	26.405	039	88.918	045	51.789	051	15.044	057	58
59	27.444	1.039	89.963	1.044	52.840	1.051	16.101	1.058	59
60	1028.483		1091.007		1153.891		1217.159		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$]

Minutes.	20° Meridional distance.	20° Difference.	21° Meridional distance.	21° Difference.	22° Meridional distance.	22° Difference.	23° Meridional distance.	23° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	1217. 159	1. 058	1280. 835	1. 065	1344. 945	1. 072	1409. 513	1. 080	0
1	18. 217	058	81. 900	065	46. 017	072	10. 593	080	1
2	19. 275	058	82. 965	065	47. 089	073	11. 673	081	2
3	20. 333	059	84. 030	065	48. 162	073	12. 754	080	3
4	21. 392	058	85. 095	066	49. 235	072	13. 834	081	4
5	22. 450	059	86. 161	065	50. 307	073	14. 915	081	5
6	23. 509	058	87. 226	066	51. 380	073	15. 996	081	6
7	24. 567	059	88. 292	065	52. 453	073	17. 077	081	7
8	25. 626	059	89. 357	066	53. 526	074	18. 158	081	8
9	26. 685	059	90. 423	066	54. 600	073	19. 239	082	9
10	1227. 744	1. 059	1291. 489	1. 066	1355. 673	1. 074	1420. 321	1. 081	10
11	28. 803	059	92. 555	066	56. 747	073	21. 402	082	11
12	29. 862	059	93. 621	067	57. 820	074	22. 484	082	12
13	30. 921	059	94. 688	066	58. 894	074	23. 566	081	13
14	31. 980	060	95. 754	067	59. 968	074	24. 647	082	14
15	33. 040	059	96. 821	066	61. 042	074	25. 729	083	15
16	34. 099	060	97. 887	067	62. 116	075	26. 812	082	16
17	35. 159	059	1298. 954	067	63. 191	074	27. 894	082	17
18	36. 218	060	1300. 021	067	64. 265	075	28. 976	083	18
19	37. 278	060	01. 088	067	65. 340	075	30. 059	083	19
20	1238. 340	1. 061	1302. 155	1. 068	1366. 415	1. 074	1431. 142	1. 083	20
21	39. 399	060	03. 223	067	67. 489	075	32. 225	083	21
22	40. 459	060	04. 290	068	68. 564	076	33. 308	083	22
23	41. 519	061	05. 358	067	69. 640	075	34. 391	083	23
24	42. 580	060	06. 425	068	70. 715	075	35. 474	083	24
25	43. 640	061	07. 493	068	71. 790	076	36. 557	084	25
26	44. 701	061	08. 561	068	72. 866	076	37. 641	084	26
27	45. 762	061	09. 629	068	73. 942	075	38. 725	084	27
28	46. 823	061	10. 697	068	75. 017	076	39. 809	084	28
29	47. 884	061	11. 765	069	76. 093	076	40. 893	084	29
30	1248. 945	1. 061	1312. 834	1. 068	1377. 169	1. 076	1441. 977	1. 084	30
31	50. 006	062	13. 902	069	78. 245	077	43. 061	085	31
32	51. 068	061	14. 971	069	79. 322	076	44. 146	084	32
33	52. 129	062	16. 040	069	80. 398	077	45. 230	085	33
34	53. 191	061	17. 109	069	81. 475	076	46. 315	085	34
35	54. 252	062	18. 178	069	82. 551	077	47. 400	085	35
36	55. 314	062	19. 247	069	83. 628	077	48. 485	085	36
37	56. 376	062	20. 316	070	84. 705	077	49. 570	085	37
38	57. 438	063	21. 386	069	85. 782	078	50. 655	086	38
39	58. 501	062	22. 455	070	86. 860	077	51. 741	085	39
40	1259. 563	1. 063	1323. 525	1. 070	1387. 937	1. 077	1452. 826	1. 086	40
41	60. 626	062	24. 595	070	89. 014	078	53. 912	086	41
42	61. 688	063	25. 665	070	90. 092	078	54. 998	086	42
43	62. 751	063	26. 735	070	91. 170	078	56. 084	086	43
44	63. 814	063	27. 805	070	92. 248	078	57. 170	086	44
45	64. 877	063	28. 875	070	93. 326	078	58. 256	087	45
46	65. 940	063	29. 945	071	94. 404	078	59. 343	086	46
47	67. 003	064	31. 016	070	95. 482	079	60. 429	087	47
48	68. 067	063	32. 086	071	96. 561	078	61. 516	087	48
49	69. 130	064	33. 157	071	97. 639	079	62. 603	087	49
50	1270. 194	1. 063	1334. 228	1. 071	1398. 718	1. 079	1463. 690	1. 086	50
51	71. 257	064	35. 299	071	1399. 797	079	64. 776	088	51
52	72. 321	064	36. 370	072	1400. 876	079	65. 864	087	52
53	73. 385	064	37. 442	071	01. 955	079	66. 951	087	53
54	74. 449	064	38. 513	072	03. 034	080	68. 038	088	54
55	75. 513	064	39. 585	072	04. 114	079	69. 126	088	55
56	76. 577	065	40. 657	071	05. 193	080	70. 214	088	56
57	77. 642	064	41. 728	072	06. 273	080	71. 302	088	57
58	78. 706	065	42. 800	072	07. 353	080	72. 390	088	58
59	79. 771	1. 064	43. 872	1. 073	08. 433	1. 080	73. 478	1. 088	59
60	1280. 835		1344. 945		1409. 513		1474. 566		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{293}$.]

Minutes	24° Meridional distance	24° Difference	25° Meridional distance	25° Difference	26° Meridional distance	26° Difference	27° Meridional distance	27° Difference	Minutes
0	1474.566	1.089	1540.134	1.097	1606.243	1.106	1672.923	1.117	0
1	75.655	088	41.231	097	07.349	107	74.040	116	1
2	76.743	089	42.328	098	08.456	107	75.156	117	2
3	77.832	089	43.426	098	09.563	107	76.273	117	3
4	78.921	089	44.524	098	10.670	107	77.390	117	4
5	80.010	089	45.622	098	11.777	107	78.507	117	5
6	81.099	090	46.720	098	12.884	108	79.624	117	6
7	82.189	089	47.818	098	13.992	107	80.741	118	7
8	83.278	090	48.916	099	15.099	108	81.859	117	8
9	84.368	090	50.015	098	16.207	108	82.976	118	9
10	1485.458	1.090	1551.113	1.099	1617.315	1.108	1684.094	1.118	10
11	86.548	090	52.212	099	18.423	109	85.212	119	11
12	87.638	090	53.311	099	19.532	108	86.331	118	12
13	88.728	091	54.410	099	20.640	109	87.449	118	13
14	89.819	090	55.509	100	21.749	109	88.567	119	14
15	90.909	091	56.609	099	22.858	109	89.686	119	15
16	92.000	091	57.708	100	23.967	109	90.805	119	16
17	93.091	091	58.808	100	25.076	109	91.924	119	17
18	94.182	091	59.908	100	26.185	110	93.043	120	18
19	95.273	091	61.008	100	27.295	109	94.163	119	19
20	1496.364	1.091	1562.108	1.101	1628.404	1.110	1695.282	1.120	20
21	97.455	092	63.209	100	29.514	110	96.402	120	21
22	98.547	092	64.309	101	30.624	110	97.522	120	22
23	1499.639	091	65.410	101	31.734	110	98.642	120	23
24	1500.730	092	66.511	101	32.844	111	1699.762	121	24
25	01.822	092	67.612	101	33.955	110	1700.883	120	25
26	02.914	093	68.713	101	35.065	111	02.003	121	26
27	04.007	092	69.814	101	36.176	111	03.124	121	27
28	05.099	093	70.915	102	37.287	111	04.245	121	28
29	06.192	092	72.017	102	38.398	111	05.366	121	29
30	1507.284	1.093	1573.119	1.102	1639.509	1.112	1706.487	1.122	30
31	08.377	093	74.221	102	40.621	112	07.609	121	31
32	09.470	093	75.323	102	41.733	111	08.730	122	32
33	10.563	093	76.425	102	42.844	112	09.852	122	33
34	11.656	094	77.527	102	43.956	112	10.974	122	34
35	12.750	093	78.629	103	45.068	113	12.096	123	35
36	13.843	094	79.732	103	46.181	112	13.219	122	36
37	14.937	094	80.835	103	47.293	113	14.341	123	37
38	16.031	094	81.938	103	48.406	112	15.464	122	38
39	17.125	094	83.041	103	49.518	113	16.586	123	39
40	1518.219	1.094	1584.144	1.104	1650.631	1.113	1717.709	1.124	40
41	19.313	095	85.248	103	51.744	113	18.833	123	41
42	20.408	094	86.351	104	52.857	114	19.956	124	42
43	21.502	095	87.455	104	53.971	113	21.080	123	43
44	22.597	095	88.559	104	55.084	114	22.203	124	44
45	23.692	095	89.663	104	56.198	114	23.327	124	45
46	24.787	095	90.767	104	57.312	114	24.451	124	46
47	25.882	096	91.871	105	58.426	114	25.575	125	47
48	26.978	095	92.976	105	59.540	114	26.700	124	48
49	28.073	096	94.081	105	60.654	115	27.824	125	49
50	1529.169	1.096	1595.186	1.105	1661.769	1.115	1728.949	1.125	50
51	30.265	096	96.291	105	62.884	114	30.074	125	51
52	31.361	096	97.396	105	63.998	115	31.199	125	52
53	32.457	096	98.501	106	65.113	116	32.324	126	53
54	33.553	097	1599.607	105	66.229	115	33.450	125	54
55	34.650	096	1600.712	106	67.344	115	34.575	126	55
56	35.746	097	01.818	106	68.459	116	35.701	126	56
57	36.843	097	02.924	106	69.575	116	36.827	126	57
58	37.940	097	04.030	106	70.691	116	37.953	127	58
59	39.037	1.097	05.136	1.107	71.807	1.116	39.080	1.126	59
60	1540.134		1606.243		1672.923		1740.206		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	28° Meridional distance.	28° Difference.	29° Meridional distance.	29° Difference.	30° Meridional distance.	30° Difference.	31° Meridional distance.	31° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	1740.206	1.127	1808.122	1.138	1876.706	1.149	1945.992	1.161	0
1	41.333	127	09.260	138	77.855	149	47.153	161	1
2	42.460	127	10.398	137	79.004	149	48.314	162	2
3	43.587	127	11.535	138	80.153	150	49.476	161	3
4	44.714	127	12.673	139	81.303	150	50.637	162	4
5	45.841	128	13.812	138	82.453	150	51.799	162	5
6	46.969	127	14.950	139	83.603	150	52.961	162	6
7	48.096	128	16.089	139	84.753	150	54.123	162	7
8	49.224	128	17.228	139	85.903	150	55.285	163	8
9	50.352	129	18.367	139	87.053	151	56.448	163	9
10	1751.481	1.128	1819.506	1.139	1888.204	1.151	1957.611	1.163	10
11	52.609	129	20.645	140	89.355	151	58.774	163	11
12	53.738	128	21.785	139	90.506	151	59.937	163	12
13	54.866	129	22.924	140	91.657	152	61.100	163	13
14	55.995	129	24.064	140	92.809	151	62.263	164	14
15	57.124	130	25.204	141	93.960	152	63.427	164	15
16	58.254	129	26.345	140	95.112	152	64.591	165	16
17	59.383	130	27.485	141	96.264	152	65.756	164	17
18	60.513	130	28.626	141	97.416	153	66.920	165	18
19	61.643	130	29.767	141	98.569	152	68.085	164	19
20	1762.773	1.130	1830.908	1.141	1899.721	1.153	1969.249	1.165	20
21	63.903	130	32.049	141	1900.874	153	70.414	166	21
22	65.033	131	33.190	142	02.027	154	71.580	165	22
23	66.164	131	34.332	142	03.181	153	72.745	166	23
24	67.295	131	35.474	142	04.334	154	73.911	166	24
25	68.426	131	36.616	142	05.488	154	75.077	166	25
26	69.557	131	37.758	142	06.642	154	76.243	166	26
27	70.688	132	38.900	143	07.796	154	77.409	166	27
28	71.820	131	40.043	143	08.950	155	78.575	167	28
29	72.951	132	41.186	143	10.105	154	79.742	167	29
30	1774.083	1.132	1842.329	1.143	1911.259	1.155	1980.909	1.167	30
31	75.215	132	43.472	143	12.414	155	82.076	168	31
32	76.347	132	44.615	144	13.569	155	83.244	167	32
33	77.479	133	45.759	143	14.724	156	84.411	168	33
34	78.612	133	46.902	144	15.880	155	85.579	168	34
35	79.745	132	48.046	144	17.035	156	86.747	168	35
36	80.877	134	49.190	145	18.191	156	87.915	169	36
37	82.011	133	50.335	144	19.347	156	89.084	168	37
38	83.144	133	51.479	145	20.503	157	90.252	169	38
39	84.277	134	52.624	145	21.660	156	91.421	169	39
40	1785.411	1.134	1853.769	1.145	1922.816	1.157	1992.590	1.169	40
41	86.545	134	54.914	145	23.973	157	93.759	170	41
42	87.679	134	56.059	145	25.130	157	94.929	169	42
43	88.813	135	57.204	146	26.287	158	96.098	170	43
44	89.948	134	58.350	146	27.445	158	97.268	170	44
45	91.082	135	59.496	146	28.603	157	98.438	171	45
46	92.217	135	60.642	146	29.760	158	1999.609	170	46
47	93.352	135	61.788	146	30.918	159	2000.779	171	47
48	94.487	135	62.934	147	32.077	158	01.950	171	48
49	95.622	136	64.081	147	33.235	159	03.121	171	49
50	1796.758	1.135	1865.228	1.147	1934.394	1.159	2004.292	1.171	50
51	97.893	136	66.375	147	35.553	159	05.463	172	51
52	1799.029	136	67.522	147	36.712	159	06.635	172	52
53	1800.165	136	68.669	148	37.871	160	07.807	172	53
54	01.301	137	69.817	147	39.031	160	08.979	172	54
55	02.438	136	70.964	148	40.191	160	10.151	172	55
56	03.574	137	72.112	148	41.351	160	11.323	173	56
57	04.711	137	73.260	149	42.511	160	12.496	173	57
58	05.848	137	74.409	148	43.671	161	13.669	173	58
59	06.985	1.137	75.557	1.149	44.832	1.160	14.842	1.173	59
60	1808.122		1876.706		1945.992		2016.015		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes	32° Meridional distance.	32° Difference	33° Meridional distance.	33° Difference	34° Meridional distance.	34° Difference	35° Meridional distance.	35° Difference	Minutes
′	′	′	′	′	′	′	′	′	
0	2016.015	1.174	2086.814	1.187	2158.428	1.201	2230.898	1.215	0
1	17.189	174	88.001	187	59.629	201	32.113	216	1
2	18.363	174	89.188	188	60.830	201	33.329	216	2
3	19.537	174	90.376	187	62.031	201	34.545	216	3
4	20.711	174	91.563	188	63.232	202	35.761	216	4
5	21.885	175	92.751	188	64.434	202	36.977	217	5
6	23.060	175	93.939	188	65.636	202	38.194	217	6
7	24.235	175	95.127	188	66.838	203	39.411	217	7
8	25.410	175	96.315	189	68.041	202	40.628	217	8
9	26.585	176	97.504	189	69.243	203	41.845	218	9
10	2027.761	1.175	2098.693	1.189	2170.446	1.203	2243.063	1.218	10
11	28.936	176	2099.882	189	71.649	204	44.281	218	11
12	30.112	176	2101.071	189	72.853	203	45.499	218	12
13	31.288	176	02.260	190	74.056	204	46.717	219	13
14	32.464	177	03.450	190	75.260	204	47.936	219	14
15	33.641	177	04.640	190	76.464	204	49.155	219	15
16	34.818	177	05.830	191	77.668	205	50.374	219	16
17	35.995	177	07.021	190	78.873	204	51.593	220	17
18	37.172	177	08.211	191	80.077	205	52.813	220	18
19	38.349	178	09.402	191	81.282	206	54.033	220	19
20	2039.527	1.178	2110.593	1.192	2182.488	1.205	2255.253	1.220	20
21	40.705	178	11.785	191	83.693	206	56.473	220	21
22	41.883	178	12.976	192	84.899	206	57.693	221	22
23	43.061	178	14.168	192	86.105	206	58.914	221	23
24	44.239	179	15.360	192	87.311	207	60.135	222	24
25	45.418	179	16.552	193	88.518	206	61.357	221	25
26	46.597	179	17.745	192	89.724	207	62.578	222	26
27	47.776	179	18.937	193	90.931	207	63.800	222	27
28	48.955	179	20.130	193	92.138	208	65.022	223	28
29	50.134	180	21.323	194	93.346	208	66.245	222	29
30	2051.314	1.181	2122.517	1.194	2194.554	1.208	2267.467	1.223	30
31	52.495	180	23.711	193	95.762	208	68.690	223	31
32	53.675	181	24.904	194	96.970	208	69.913	224	32
33	54.856	180	26.098	195	98.178	208	71.137	224	33
34	56.036	181	27.293	194	2199.386	209	72.361	224	34
35	57.217	182	28.487	195	2200.595	209	73.585	224	35
36	58.399	181	29.682	195	01.804	210	74.809	224	36
37	59.580	182	30.877	195	03.014	209	76.033	225	37
38	60.762	182	32.072	196	04.223	210	77.258	225	38
39	61.944	182	33.268	196	05.433	210	78.483	225	39
40	2063.126	1.182	2134.464	1.196	2206.643	1.211	2279.708	1.226	40
41	64.308	183	35.660	196	07.854	211	80.934	225	41
42	65.491	183	36.856	196	09.065	211	82.159	226	42
43	66.674	183	38.052	197	10.276	211	83.385	227	43
44	67.857	183	39.249	197	11.487	211	84.612	226	44
45	69.040	183	40.446	197	12.698	212	85.838	227	45
46	70.223	184	41.643	198	13.910	212	87.065	227	46
47	71.407	184	42.841	197	15.122	212	88.292	227	47
48	72.591	184	44.038	198	16.334	212	89.519	228	48
49	73.775	184	45.236	198	17.546	213	90.747	228	49
50	2074.959	1.185	2146.434	1.199	2218.759	1.213	2291.975	1.228	50
51	76.144	184	47.633	198	19.972	213	93.203	228	51
52	77.328	185	48.831	199	21.185	213	94.431	229	52
53	78.513	185	50.030	199	22.398	213	95.660	229	53
54	79.698	186	51.229	199	23.611	214	96.889	229	54
55	80.884	185	52.428	1.199	24.825	214	98.118	229	55
56	82.069	186	53.627	1.200	26.039	214	2299.347	230	56
57	83.255	186	54.827	200	27.253	215	2300.577	230	57
58	84.441	187	56.027	200	28.468	215	01.807	230	58
59	85.628	1.186	57.227	1.201	29.683	1.215	03.037	1.230	59
60	2086.814		2158.428		2230.898		2304.267		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	36° Meridional distance.	36° Difference.	37° Meridional distance.	37° Difference.	38° Meridional distance.	38° Difference.	39° Meridional distance.	39° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	2304. 267	1. 231	2378. 581	1. 247	2453. 888	1. 264	2530. 238	1. 281	0
1	05. 498	231	79. 828	247	55. 152	264	31. 519	282	1
2	06. 729	231	81. 075	248	56. 416	264	32. 801	282	2
3	07. 960	232	82. 323	247	57. 680	265	34. 083	283	3
4	09. 192	231	83. 570	248	58. 945	265	35. 366	283	4
5	10. 423	232	84. 818	248	60. 210	265	36. 649	283	5
6	11. 655	232	86. 066	249	61. 475	266	37. 932	283	6
7	12. 887	233	87. 315	249	62. 741	266	39. 215	284	7
8	14. 120	233	88. 564	249	64. 007	266	40. 499	284	8
9	15. 353	233	89. 813	249	65. 273	266	41. 783	285	9
10	2316. 586	1. 233	2391. 062	1. 250	2466. 539	1. 267	2543. 068	1. 284	10
11	17. 819	234	92. 312	250	67. 806	267	44. 352	285	11
12	19. 053	234	93. 562	250	69. 073	267	45. 637	285	12
13	20. 287	234	94. 812	250	70. 340	268	46. 922	286	13
14	21. 521	234	96. 062	251	71. 608	268	48. 208	286	14
15	22. 755	235	97. 313	251	72. 876	268	49. 494	287	15
16	23. 990	235	98. 564	252	74. 144	269	50. 781	286	16
17	25. 225	235	2399. 816	251	75. 413	268	52. 067	287	17
18	26. 460	235	2401. 067	252	76. 681	269	53. 354	287	18
19	27. 695	236	02. 319	252	77. 950	270	54. 641	288	19
20	2328. 931	1. 236	2403. 571	1. 253	2479. 220	1. 269	2555. 929	1. 287	20
21	30. 167	237	04. 824	252	80. 489	270	57. 216	288	21
22	31. 404	236	06. 076	253	81. 759	271	58. 504	289	22
23	32. 640	237	07. 329	253	83. 030	270	59. 793	288	23
24	33. 877	237	08. 582	254	84. 300	271	61. 081	289	24
25	35. 114	237	09. 836	254	85. 571	271	62. 370	290	25
26	36. 351	238	11. 090	254	86. 842	272	63. 660	289	26
27	37. 589	238	12. 344	254	88. 114	271	64. 949	290	27
28	38. 827	238	13. 598	255	89. 385	272	66. 239	290	28
29	40. 065	238	14. 853	255	90. 657	273	67. 529	291	29
30	2341. 303	1. 239	2416. 108	1. 255	2491. 930	1. 272	2568. 820	1. 291	30
31	42. 542	239	17. 363	255	93. 202	273	70. 111	291	31
32	43. 781	239	18. 618	256	94. 475	273	71. 402	292	32
33	45. 020	240	19. 874	256	95. 748	274	72. 694	292	33
34	46. 260	240	21. 130	256	97. 022	274	73. 986	292	34
35	47. 500	240	22. 386	257	98. 296	274	75. 278	292	35
36	48. 740	240	23. 643	257	2499. 570	274	76. 570	293	36
37	49. 980	241	24. 900	257	2500. 844	275	77. 863	293	37
38	51. 221	241	26. 157	258	02. 119	275	79. 156	293	38
39	52. 462	241	27. 415	257	03. 394	275	80. 449	294	39
40	2353. 703	1. 241	2428. 672	1. 258	2504. 669	1. 276	2581. 743	1. 294	40
41	54. 944	241	29. 930	259	05. 945	276	83. 037	294	41
42	56. 185	242	31. 189	259	07. 221	276	84. 331	295	42
43	57. 427	242	32. 448	259	08. 497	276	85. 626	295	43
44	58. 669	243	33. 707	259	09. 773	277	86. 921	295	44
45	59. 912	242	34. 966	259	11. 050	277	88. 216	295	45
46	61. 154	243	36. 225	260	12. 327	277	89. 511	296	46
47	62. 397	244	37. 485	260	13. 604	278	90. 807	296	47
48	63. 641	243	38. 745	261	14. 882	278	92. 103	297	48
49	64. 884	244	40. 006	260	16. 160	278	93. 400	297	49
50	2366. 128	1. 244	2441. 266	1. 261	2517. 438	1. 279	2594. 697	1. 297	50
51	67. 372	244	42. 527	261	18. 717	279	95. 994	298	51
52	68. 616	245	43. 788	262	19. 996	279	97. 292	298	52
53	69. 861	245	45. 050	261	21. 275	279	98. 590	298	53
54	71. 106	245	46. 311	262	22. 554	280	2599. 888	298	54
55	72. 351	246	47. 573	263	23. 834	280	2601. 186	299	55
56	73. 597	245	48. 836	262	25. 114	281	02. 485	1. 299	56
57	74. 842	246	50. 098	263	26. 395	280	03. 784	1. 300	57
58	76. 088	247	51. 361	263	27. 675	281	05. 084	1. 299	58
59	77. 335	1. 246	52. 624	1. 264	28. 956	1. 282	06. 383	1. 300	59
60	2378. 581		2453. 888		2530. 238		2607. 683		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	40° Meridional distance.	40° Difference.	41° Meridional distance.	41° Difference.	42° Meridional distance.	42° Difference.	43° Meridional distance.	43° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	2607.683	1.301	2686.280	1.320	2766.089	1.341	2847.171	1.362	0
1	08.984	300	87.600	320	67.430	341	48.533	363	1
2	10.284	301	88.920	321	68.771	341	49.896	364	2
3	11.585	301	90.241	321	70.112	342	51.260	363	3
4	12.886	302	91.562	322	71.454	342	52.623	364	4
5	14.188	302	92.884	322	72.796	342	53.987	365	5
6	15.490	302	94.206	322	74.138	343	55.352	364	6
7	16.792	303	95.528	322	75.481	343	56.716	365	7
8	18.095	303	96.850	323	76.824	344	58.081	366	8
9	19.398	303	98.173	323	78.168	344	59.447	366	9
10	2620.701	1.303	2699.496	1.324	2779.512	1.344	2860.813	1.366	10
11	22.004	304	2700.820	323	80.856	345	62.179	367	11
12	23.308	304	02.143	324	82.201	345	63.546	367	12
13	24.612	305	03.467	325	83.546	345	64.913	367	13
14	25.917	305	04.792	325	84.891	346	66.280	368	14
15	27.222	305	06.117	325	86.237	346	67.648	368	15
16	28.527	306	07.442	325	87.583	347	69.016	368	16
17	29.833	306	08.767	326	88.930	347	70.384	369	17
18	31.139	306	10.093	326	90.277	347	71.753	370	18
19	32.445	306	11.419	327	91.624	347	73.123	369	19
20	2633.751	1.307	2712.746	1.327	2792.971	1.348	2874.492	1.370	20
21	35.058	307	14.073	327	94.319	348	75.862	371	21
22	36.365	307	15.400	327	95.667	349	77.233	371	22
23	37.672	308	16.727	328	97.016	349	78.604	371	23
24	38.980	308	18.055	328	98.365	349	79.975	372	24
25	40.288	309	19.383	329	2799.714	350	81.347	372	25
26	41.597	309	20.712	329	2801.064	350	82.719	372	26
27	42.906	309	22.041	329	02.414	350	84.091	373	27
28	44.215	309	23.370	330	03.764	351	85.464	373	28
29	45.524	310	24.700	330	05.115	351	86.837	374	29
30	2646.834	1.310	2726.030	1.330	2806.466	1.352	2888.211	1.374	30
31	48.144	310	27.360	330	07.818	352	89.585	374	31
32	49.454	311	28.690	331	09.170	352	90.959	374	32
33	50.765	311	30.021	331	10.522	353	92.333	375	33
34	52.076	312	31.352	332	11.875	353	93.708	376	34
35	53.388	312	32.684	332	13.228	353	95.084	376	35
36	54.700	312	34.016	332	14.581	354	96.460	376	36
37	56.012	312	35.348	333	15.935	354	97.836	376	37
38	57.324	313	36.681	333	17.289	354	2899.212	377	38
39	58.637	313	38.014	333	18.643	355	2900.589	377	39
40	2659.950	1.313	2739.347	1.334	2819.998	1.355	2901.966	1.378	40
41	61.263	314	40.681	334	21.353	356	03.344	378	41
42	62.577	314	42.015	335	22.709	356	04.722	378	42
43	63.891	314	43.350	334	24.065	356	06.100	379	43
44	65.205	315	44.684	335	25.421	356	07.479	379	44
45	66.520	315	46.019	336	26.777	357	08.858	380	45
46	67.835	315	47.355	336	28.134	358	10.238	380	46
47	69.150	316	48.691	336	29.492	358	11.618	380	47
48	70.466	316	50.027	336	30.850	358	12.998	381	48
49	71.782	317	51.363	337	32.208	358	14.379	381	49
50	2673.099	1.316	2752.700	1.338	2833.566	1.359	2915.760	1.382	50
51	74.415	317	54.038	337	34.925	359	17.142	382	51
52	75.732	317	55.375	338	36.284	359	18.524	382	52
53	77.049	318	56.713	339	37.643	360	19.906	383	53
54	78.367	318	58.052	338	39.003	361	21.289	383	54
55	79.685	318	59.390	339	40.364	360	22.672	384	55
56	81.003	319	60.729	340	41.724	361	24.056	384	56
57	82.322	319	62.069	340	43.085	362	25.440	384	57
58	83.641	319	63.409	340	44.447	362	26.824	385	58
59	84.960	1.320	64.749	1.340	45.809	1.362	28.209	1.385	59
60	2686.280		2766.089		2847.171		2929.594		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	44° Meridional distance.	44° Difference.	45° Meridional distance.	45° Difference.	46° Meridional distance.	46° Difference.	47° Meridional distance.	47° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	2929.594	1.385	3013.427	1.410	3098.747	1.435	3185.634	1.462	0
1	30.979	386	14.837	410	3100.182	435	87.096	462	1
2	32.365	386	16.247	410	01.617	436	88.558	463	2
3	33.751	387	17.657	411	03.053	437	90.021	463	3
4	35.138	387	19.068	411	04.490	437	91.484	464	4
5	36.525	388	20.479	412	05.927	437	92.948	464	5
6	37.913	387	21.891	412	07.364	438	94.412	464	6
7	39.300	388	23.303	413	08.802	438	95.876	465	7
8	40.688	389	24.716	413	10.240	438	97.341	466	8
9	42.077	389	26.129	413	11.678	439	3198.807	466	9
10	2943.466	1.389	3027.542	1.414	3113.117	1.440	3200.273	1.466	10
11	44.855	390	28.956	414	14.557	440	01.739	467	11
12	46.245	390	30.370	414	15.997	440	03.206	468	12
13	47.635	391	31.784	415	17.437	441	04.674	468	13
14	49.026	391	33.199	416	18.878	441	06.142	468	14
15	50.417	391	34.615	416	20.319	442	07.610	469	15
16	51.808	392	36.031	416	21.761	442	09.079	469	16
17	53.200	392	37.447	416	23.203	442	10.548	470	17
18	54.592	393	38.863	417	24.645	443	12.018	470	18
19	55.985	393	40.280	418	26.088	443	13.488	471	19
20	2957.378	1.393	3041.698	1.418	3127.531	1.444	3214.959	1.471	20
21	58.771	394	43.116	418	28.975	444	16.430	472	21
22	60.165	394	44.534	419	30.419	445	17.902	472	22
23	61.559	394	45.953	420	31.864	445	19.374	472	23
24	62.953	395	47.373	419	33.309	446	20.846	473	24
25	64.348	396	48.792	420	34.755	446	22.319	474	25
26	65.744	396	50.212	421	36.201	446	23.793	474	26
27	67.140	396	51.633	421	37.647	447	25.267	474	27
28	68.536	396	53.054	421	39.094	447	26.741	475	28
29	69.932	397	54.475	422	40.541	448	28.216	475	29
30	2971.329	1.398	3055.897	1.422	3141.989	1.449	3229.691	1.476	30
31	72.727	397	57.319	422	43.438	448	31.167	476	31
32	74.124	398	58.741	423	44.886	449	32.643	477	32
33	75.522	399	60.164	424	46.335	450	34.120	477	33
34	76.921	399	61.588	424	47.785	450	35.597	478	34
35	78.320	399	63.012	424	49.235	451	37.075	478	35
36	79.719	400	64.436	424	50.686	451	38.553	479	36
37	81.119	400	65.860	426	52.137	451	40.032	479	37
38	82.519	401	67.286	425	53.588	452	41.511	480	38
39	83.920	401	68.711	426	55.040	452	42.991	480	39
40	2985.321	1.401	3070.137	1.427	3156.492	1.453	3244.471	1.480	40
41	86.722	402	71.564	427	57.945	453	45.951	481	41
42	88.124	403	72.991	427	59.398	454	47.432	482	42
43	89.527	402	74.418	428	60.852	454	48.914	482	43
44	90.929	403	75.846	428	62.306	455	50.396	482	44
45	92.332	404	77.274	428	63.761	455	51.878	483	45
46	93.736	404	78.702	429	65.216	455	53.361	483	46
47	95.140	404	80.131	430	66.671	456	54.844	484	47
48	96.544	405	81.561	430	68.127	457	56.328	485	48
49	97.949	405	82.991	430	69.584	457	57.813	485	49
50	2999.354	1.405	3084.421	1.431	3171.041	1.457	3259.298	1.485	50
51	3000.759	406	85.852	431	72.498	458	60.783	486	51
52	02.165	407	87.283	431	73.956	458	62.269	486	52
53	03.572	406	88.714	432	75.414	459	63.755	487	53
54	04.978	407	90.146	432	76.873	459	65.242	487	54
55	06.385	408	91.578	433	78.332	459	66.729	488	55
56	07.793	408	93.011	433	79.791	460	68.217	488	56
57	09.201	408	94.444	434	81.251	461	69.705	489	57
58	10.609	409	95.878	434	82.712	461	71.194	489	58
59	12.018	1.409	97.312	1.435	84.173	1.461	72.683	1.490	59
60	3013.427		3098.747		3185.634		3274.173		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{291}$.]

Minutes.	48° Meridional distance.	48° Difference.	49° Meridional distance.	49° Difference.	50° Meridional distance.	50° Difference.	51° Meridional distance.	51° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	3274.173	1.490	3364.456	1.520	3456.581	1.551	3550.654	1.585	0
1	75.663	491	65.976	521	58.132	552	52.239	585	1
2	77.154	491	67.497	521	59.684	553	53.824	586	2
3	78.645	491	69.018	521	61.237	553	55.410	587	3
4	80.136	493	70.539	522	62.790	554	56.997	587	4
5	81.629	492	72.061	523	64.344	555	58.584	588	5
6	83.121	493	73.584	523	65.899	555	60.172	589	6
7	84.614	494	75.107	524	67.454	555	61.761	589	7
8	86.108	494	76.631	524	69.009	556	63.350	589	8
9	87.602	494	78.155	525	70.565	557	64.939	590	9
10	3289.096	1.495	3379.680	1.525	3472.122	1.557	3566.529	1.591	10
11	90.591	496	81.205	526	73.679	557	68.120	592	11
12	92.087	496	82.731	526	75.236	558	69.712	592	12
13	93.583	496	84.257	526	76.794	559	71.304	592	13
14	95.079	497	85.783	527	78.353	559	72.896	593	14
15	96.576	498	87.310	528	79.912	560	74.489	594	15
16	98.074	498	88.838	529	81.472	561	76.083	594	16
17	3299.572	498	90.367	529	83.033	561	77.677	595	17
18	3301.070	499	91.896	529	84.594	561	79.272	596	18
19	02.569	500	93.425	530	86.155	562	80.868	596	19
20	3304.069	1.500	3394.955	1.530	3487.717	1.563	3582.464	1.596	20
21	05.569	500	96.485	531	89.280	563	84.060	597	21
22	07.069	501	98.016	531	90.843	563	85.657	598	22
23	08.570	501	3399.547	532	92.406	564	87.255	598	23
24	10.071	502	3401.079	533	93.970	565	88.853	599	24
25	11.573	502	02.612	533	95.535	565	90.452	600	25
26	13.075	503	04.145	533	97.100	566	92.052	600	26
27	14.578	504	05.678	534	3498.666	567	93.652	600	27
28	16.082	504	07.212	535	3500.233	567	95.252	601	28
29	17.586	504	08.747	535	01.800	567	96.853	602	29
30	3319.090	1.505	3410.282	1.535	3503.367	1.568	3598.455	1.603	30
31	20.595	505	11.817	536	04.935	569	3600.058	603	31
32	22.100	506	13.353	537	06.504	569	01.661	604	32
33	23.606	507	14.890	537	08.073	570	03.265	604	33
34	25.113	507	16.427	538	09.643	570	04.869	605	34
35	26.620	507	17.965	538	11.213	571	06.474	605	35
36	28.127	508	19.503	539	12.784	571	08.079	606	36
37	29.635	508	21.042	539	14.355	572	09.685	607	37
38	31.143	509	22.581	540	15.927	573	11.292	607	38
39	32.652	510	24.121	540	17.500	573	12.899	607	39
40	3334.162	1.510	3425.661	1.541	3519.073	1.574	3614.506	1.609	40
41	35.672	510	27.202	542	20.647	574	16.115	609	41
42	37.182	511	28.744	542	22.221	575	17.724	610	42
43	38.693	511	30.286	542	23.796	575	19.334	610	43
44	40.204	512	31.828	543	25.371	576	20.944	611	44
45	41.716	512	33.371	544	26.947	577	22.555	611	45
46	43.228	513	34.915	544	28.524	577	24.166	612	46
47	44.741	514	36.459	545	30.101	577	25.778	612	47
48	46.255	514	38.004	545	31.678	578	27.390	613	48
49	47.769	514	39.549	546	33.256	579	29.003	614	49
50	3349.283	1.515	3441.095	1.546	3534.835	1.580	3630.617	1.614	50
51	50.798	516	42.641	547	36.415	580	32.231	615	51
52	52.314	516	44.188	547	37.995	580	33.846	616	52
53	53.830	516	45.735	548	39.575	581	35.462	616	53
54	55.346	517	47.283	548	41.156	581	37.078	617	54
55	56.863	518	48.831	549	42.737	582	38.695	617	55
56	58.381	518	50.380	549	44.319	583	40.312	618	56
57	59.899	518	51.929	550	45.902	583	41.930	618	57
58	61.417	519	53.479	551	47.485	584	43.548	619	58
59	62.936	1.520	55.030	1.551	49.069	1.585	45.167	1.620	59
60	3364.456		3456.581		3550.654		3646.787		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	52° Meridional distance.	52° Difference.	53° Meridional distance.	53° Difference.	54° Meridional distance.	54° Difference.	55° Meridional distance.	55° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	3646. 787	1. 621	3745. 105	1. 658	3845. 738	1. 698	3948. 830	1. 740	0
1	48. 408	621	46. 763	658	47. 436	698	50. 570	741	1
2	50. 029	621	48. 421	659	49. 134	699	52. 311	741	2
3	51. 650	622	50. 080	660	50. 833	700	54. 052	742	3
4	53. 272	623	51. 740	661	52. 533	701	55. 794	743	4
5	54. 895	624	53. 401	661	54. 234	701	57. 537	744	5
6	56. 519	624	55. 062	662	55. 935	702	59. 281	744	6
7	58. 143	624	56. 724	662	57. 637	702	61. 025	745	7
8	59. 767	626	58. 386	663	59. 339	703	62. 770	746	8
9	61. 393	626	60. 049	664	61. 042	704	64. 516	746	9
10	3663. 019	1. 626	3761. 713	1. 664	3862. 746	1. 704	3966. 262	1. 747	10
11	64. 645	627	63. 377	665	64. 450	705	68. 009	748	11
12	66. 272	628	65. 042	666	66. 155	706	69. 757	749	12
13	67. 900	628	66. 708	666	67. 861	707	71. 506	749	13
14	69. 528	629	68. 374	667	69. 568	707	73. 255	750	14
15	71. 157	630	70. 041	668	71. 275	708	75. 005	751	15
16	72. 787	630	71. 709	668	72. 983	708	76. 756	752	16
17	74. 417	631	73. 377	669	74. 691	709	78. 508	752	17
18	76. 048	631	75. 046	669	76. 400	710	80. 260	753	18
19	77. 679	632	76. 715	670	78. 110	711	82. 013	754	19
20	3679. 311	1. 633	3778. 385	1. 671	3879. 821	1. 712	3983. 767	1. 755	20
21	80. 944	633	80. 056	672	81. 533	712	85. 522	755	21
22	82. 577	634	81. 728	672	83. 245	713	87. 277	756	22
23	84. 211	634	83. 400	673	84. 958	714	89. 033	757	23
24	85. 845	635	85. 073	673	86. 672	714	90. 790	758	24
25	87. 480	636	86. 746	674	88. 386	715	92. 548	758	25
26	89. 116	636	88. 420	675	90. 101	715	94. 306	759	26
27	90. 752	637	90. 095	676	91. 816	717	96. 065	760	27
28	92. 389	638	91. 771	676	93. 533	717	97. 825	761	28
29	94. 027	638	93. 447	677	95. 250	717	3999. 586	761	29
30	3695. 665	1. 639	3795. 124	1. 677	3896. 967	1. 719	4001. 347	1. 762	30
31	97. 304	639	96. 801	678	3898. 686	719	03. 109	763	31
32	3698. 943	640	3798. 479	679	3900. 405	720	04. 872	763	32
33	3700. 583	641	3800. 158	679	02. 125	720	06. 635	764	33
34	02. 224	642	01. 837	680	03. 845	721	08. 399	765	34
35	03. 866	642	03. 517	681	05. 566	722	10. 164	766	35
36	05. 508	642	05. 198	681	07. 288	723	11. 930	767	36
37	07. 150	643	06. 879	682	09. 011	723	13. 697	767	37
38	08. 793	644	08. 561	683	10. 734	724	15. 464	768	38
39	10. 437	645	10. 244	684	12. 458	725	17. 232	769	39
40	3712. 082	1. 645	3811. 928	1. 684	3914. 183	1. 726	4019. 001	1. 769	40
41	13. 727	646	13. 612	685	15. 909	726	20. 770	771	41
42	15. 373	646	15. 297	685	17. 635	727	22. 541	771	42
43	17. 019	647	16. 982	686	19. 362	728	24. 312	772	43
44	18. 666	648	18. 668	687	21. 090	728	26. 084	772	44
45	20. 314	648	20. 355	688	22. 818	729	27. 856	774	45
46	21. 962	649	22. 043	688	24. 547	730	29. 630	774	46
47	23. 611	650	23. 731	689	26. 277	731	31. 404	775	47
48	25. 261	650	25. 420	689	28. 008	731	33. 179	776	48
49	26. 911	651	27. 109	690	29. 739	732	34. 955	776	49
50	3728. 562	1. 651	3828. 799	1. 691	3931. 471	1. 732	4036. 731	1. 777	50
51	30. 213	652	30. 490	692	33. 203	734	38. 508	778	51
52	31. 865	653	32. 182	692	34. 937	734	40. 286	779	52
53	33. 518	653	33. 874	693	36. 671	735	42. 065	779	53
54	35. 171	654	35. 567	694	38. 406	736	43. 844	780	54
55	36. 825	655	37. 261	694	40. 142	736	45. 624	781	55
56	38. 480	655	38. 955	695	41. 878	737	47. 405	782	56
57	40. 135	656	40. 650	695	43. 615	738	49. 187	783	57
58	41. 791	656	42. 345	696	45. 353	738	50. 970	783	58
59	43. 447	1. 658	44. 041	1. 697	47. 091	1. 739	52. 753	1. 784	59
60	3745. 105		3845. 738		3948. 830		4054. 537		60

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	56° Meridional distance.	56° Difference.	57° Meridional distance.	57° Difference.	58° Meridional distance.	58° Difference.	59° Meridional distance.	59° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	4054. 537	1. 784	4163. 027	1. 833	4274. 485	1. 884	4389. 113	1. 939	0
1	56. 321	785	64. 860	833	76. 369	885	91. 052	939	1
2	58. 106	786	66. 693	834	78. 254	885	92. 991	941	2
3	59. 892	787	68. 527	836	80. 139	887	94. 932	941	3
4	61. 679	788	70. 363	836	82. 026	887	96. 873	942	4
5	63. 467	788	72. 199	837	83. 913	888	4398. 815	944	5
6	65. 255	789	74. 036	837	85. 801	890	4400. 759	944	6
7	67. 044	790	75. 873	839	87. 691	890	02. 703	945	7
8	68. 834	791	77. 712	839	89. 581	891	04. 648	946	8
9	70. 625	792	79. 551	840	91. 472	892	06. 594	947	9
10	4072. 417	1. 793	4181. 391	1. 841	4293. 364	1. 892	4408. 541	1. 948	10
11	74. 210	794	83. 232	842	95. 256	894	10. 489	949	11
12	76. 004	795	85. 074	843	97. 150	895	12. 438	950	12
13	77. 799	795	86. 917	844	4299. 045	895	14. 388	951	13
14	79. 594	796	88. 761	844	4300. 940	896	16. 339	952	14
15	81. 390	797	90. 605	846	02. 836	898	18. 291	953	15
16	83. 187	797	92. 451	846	04. 734	898	20. 244	953	16
17	84. 984	799	94. 297	847	06. 632	899	22. 197	955	17
18	86. 783	799	96. 144	848	08. 531	900	24. 152	956	18
19	88. 582	800	97. 992	848	10. 431	901	26. 108	956	19
20	4090. 382	1. 800	4199. 840	1. 850	4312. 332	1. 901	4428. 064	1. 958	20
21	92. 182	801	4201. 690	850	14. 233	903	30. 022	959	21
22	93. 983	802	03. 540	851	16. 136	904	31. 981	959	22
23	95. 785	803	05. 391	852	18. 040	904	33. 940	961	23
24	97. 588	804	07. 243	852	19. 944	905	35. 901	961	24
25	4099. 392	805	09. 095	854	21. 849	906	37. 862	963	25
26	4101. 197	805	10. 949	854	23. 755	908	39. 825	963	26
27	03. 002	806	12. 804	855	25. 663	908	41. 788	965	27
28	04. 808	807	14. 659	856	27. 571	909	43. 753	965	28
29	06. 615	808	16. 515	857	29. 480	909	45. 718	966	29
30	4108. 423	1. 808	4218. 372	1. 858	4331. 389	1. 911	4447. 684	1. 968	30
31	10. 231	809	20. 230	859	33. 300	912	49. 652	968	31
32	12. 040	810	22. 089	860	35. 212	913	51. 620	969	32
33	13. 850	811	23. 949	860	37. 125	913	53. 589	971	33
34	15. 661	812	25. 809	862	39. 038	915	55. 560	971	34
35	17. 473	812	27. 671	862	40. 953	915	57. 531	972	35
36	19. 285	813	29. 533	863	42. 868	916	59. 503	973	36
37	21. 098	814	31. 396	864	44. 784	917	61. 476	975	37
38	22. 912	815	33. 260	865	46. 701	918	63. 451	975	38
39	24. 727	816	35. 125	866	48. 619	919	65. 426	976	39
40	4126. 543	1. 817	4236. 991	1. 866	4350. 538	1. 920	4467. 402	1. 977	40
41	28. 360	817	38. 857	867	52. 458	921	69. 379	978	41
42	30. 177	818	40. 724	868	54. 379	922	71. 357	979	42
43	31. 995	819	42. 592	869	56. 301	923	73. 336	981	43
44	33. 814	820	44. 461	870	58. 224	924	75. 317	981	44
45	35. 634	820	46. 331	871	60. 148	924	77. 298	982	45
46	37. 454	821	48. 202	872	62. 072	925	79. 280	983	46
47	39. 275	822	50. 074	872	63. 997	927	81. 263	984	47
48	41. 097	823	51. 946	873	65. 924	927	83. 247	985	48
49	42. 920	824	53. 819	875	67. 851	928	85. 232	986	49
50	4144. 744	1. 825	4255. 694	1. 875	4369. 779	1. 930	4487. 218	1. 987	50
51	46. 569	825	57. 569	876	71. 709	930	89. 205	988	51
52	48. 394	826	59. 445	877	73. 639	931	91. 193	989	52
53	50. 220	827	61. 322	878	75. 570	932	93. 182	990	53
54	52. 047	828	63. 200	879	77. 502	932	95. 172	991	54
55	53. 875	829	65. 079	879	79. 434	934	97. 163	992	55
56	55. 704	830	66. 958	881	81. 368	935	4499. 155	993	56
57	57. 534	830	68. 839	881	83. 303	936	4501. 148	994	57
58	59. 364	831	70. 720	882	85. 239	936	03. 142	995	58
59	61. 195	1. 832	72. 602	1. 883	87. 175	1. 938	05. 137	1. 996	59
60	4163. 027		4274. 485		4389. 113		4507. 133		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	60° Meridional distance.	60° Difference	61° Meridional distance.	61° Difference	62° Meridional distance.	62° Difference	63° Meridional distance.	63° Difference	Minutes.
	′	′	′	′	′	′	′	′	
0	4507.133	1.997	4628.789	2.060	4754.350	2.128	4884.117	2.200	0
1	09.130	998	30.849	061	56.478	129	86.317	201	1
2	11.128	1.999	32.910	062	58.607	129	88.518	203	2
3	13.127	2.001	34.972	063	60.736	131	90.721	204	3
4	15.128	001	37.035	064	62.867	133	92.925	205	4
5	17.129	002	39.099	066	65.000	133	95.130	206	5
6	19.131	003	41.165	066	67.133	135	97.336	208	6
7	21.134	005	43.231	068	69.268	135	4899.544	209	7
8	23.139	005	45.299	069	71.403	137	4901.753	211	8
9	25.144	006	47.368	069	73.540	138	03.964	211	9
10	4527.150	2.007	4649.437	2.071	4775.678	2.139	4906.175	2.213	10
11	29.157	009	51.508	072	77.817	141	08.388	215	11
12	31.166	009	53.580	073	79.958	141	10.603	215	12
13	33.175	010	55.653	074	82.099	143	12.818	217	13
14	35.185	012	57.727	075	84.242	144	15.035	218	14
15	37.197	012	59.802	077	86.386	145	17.253	219	15
16	39.209	013	61.879	077	88.531	146	19.472	221	16
17	41.222	015	63.956	079	90.677	148	21.693	222	17
18	43.237	015	66.035	079	92.825	148	23.915	223	18
19	45.252	017	68.114	081	94.973	150	26.138	224	19
20	4547.269	2.017	4670.195	2.082	4797.123	2.151	4928.362	2.226	20
21	49.286	019	72.277	083	4799.274	153	30.588	227	21
22	51.305	019	74.360	084	4801.427	153	32.815	228	22
23	53.324	021	76.444	085	03.580	155	35.043	230	23
24	55.345	022	78.529	086	05.735	156	37.273	231	24
25	57.367	022	80.615	088	07.891	157	39.504	232	25
26	59.389	024	82.703	088	10.048	158	41.736	234	26
27	61.143	025	84.791	090	12.206	160	43.970	234	27
28	63.438	026	86.881	091	14.366	160	46.204	237	28
29	65.464	027	88.972	092	16.526	162	48.441	237	29
30	4567.491	2.028	4691.064	2.093	4818.688	2.163	4950.678	2.239	30
31	69.519	028	93.157	094	20.851	165	52.917	240	31
32	71.547	030	95.251	095	23.016	165	55.157	241	32
33	73.577	032	97.346	097	25.181	167	57.398	243	33
34	75.609	032	4699.443	097	27.348	168	59.641	244	34
35	77.641	033	4701.540	099	29.516	169	61.885	245	35
36	79.674	034	03.639	100	31.685	171	64.130	247	36
37	81.708	035	05.739	101	33.856	171	66.377	248	37
38	83.743	037	07.840	102	36.027	173	68.625	249	38
39	85.780	037	09.942	103	38.200	174	70.874	251	39
40	4587.817	2.039	4712.045	2.104	4840.374	2.176	4973.125	2.252	40
41	89.856	039	14.149	106	42.550	176	75.377	253	41
42	91.895	041	16.255	106	44.726	178	77.630	255	42
43	93.936	042	18.361	108	46.904	179	79.885	256	43
44	95.978	042	20.469	109	49.083	180	82.141	257	44
45	4598.020	044	22.578	110	51.263	182	84.398	259	45
46	4600.064	045	24.688	111	53.445	183	86.657	260	46
47	02.109	046	26.799	113	55.628	184	88.917	261	47
48	04.155	047	28.912	113	57.812	185	91.178	263	48
49	06.202	048	31.025	115	59.997	186	93.441	263	49
50	4608.250	2.049	4733.140	2.116	4862.183	2.188	4995.704	2.266	50
51	10.299	050	35.256	117	64.371	189	4997.970	266	51
52	12.349	051	37.373	118	66.560	190	5000.236	268	52
53	14.400	052	39.491	119	68.750	192	02.504	270	53
54	16.452	054	41.610	121	70.942	192	04.774	271	54
55	18.506	054	43.731	121	73.134	194	07.045	272	55
56	20.560	056	45.852	123	75.328	196	09.317	273	56
57	22.616	056	47.975	124	77.524	196	11.590	275	57
58	24.672	058	50.099	125	79.720	198	13.865	276	58
59	26.730	2.059	52.224	2.126	81.918	2.199	16.141	2.278	59
60	4628.789		4754.350		4884.117		5018.419		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	64° Meridional distance.	64° Difference.	65° Meridional distance.	65° Difference.	66° Meridional distance.	66° Difference.	67° Meridional distance.	67° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	5018.419	2.279	5157.629	2.364	5302.164	2.457	5452.493	2.558	0
1	20.698	280	59.993	366	04.621	458	55.051	559	1
2	22.978	281	62.359	367	07.079	459	57.610	561	2
3	25.259	283	64.726	368	09.538	461	60.171	563	3
4	27.542	285	67.094	370	11.999	464	62.734	564	4
5	29.827	286	69.464	371	14.463	465	65.298	567	5
6	32.113	287	71.835	373	16.928	466	67.865	568	6
7	34.400	288	74.208	375	19.394	468	70.433	570	7
8	36.688	290	76.583	376	21.862	469	73.003	571	8
9	38.978	291	78.959	378	24.331	471	75.574	574	9
10	5041.269	2.293	5181.337	2.379	5326.802	2.473	5478.148	2.576	10
11	43.562	294	83.716	380	29.275	475	80.724	577	11
12	45.856	295	86.096	382	31.750	476	83.301	579	12
13	48.151	296	88.478	383	34.226	478	85.880	581	13
14	50.447	298	90.861	385	36.704	479	88.461	582	14
15	52.745	300	93.246	386	39.183	481	91.043	584	15
16	55.045	301	95.632	388	41.664	483	93.627	586	16
17	57.346	302	5198.020	390	44.147	484	96.213	588	17
18	59.648	304	5200.410	391	46.631	486	5498.801	589	18
19	61.952	305	02.801	393	49.117	488	5501.390	591	19
20	5064.257	2.306	5205.194	2.394	5351.605	2.489	5503.981	2.592	20
21	66.563	308	07.588	395	54.094	491	06.573	593	21
22	68.871	309	09.983	397	56.585	493	09.166	595	22
23	71.180	311	12.380	399	59.078	494	11.761	597	23
24	73.491	312	14.779	400	61.572	496	14.358	599	24
25	75.803	314	17.179	402	64.068	497	16.957	602	25
26	78.117	315	19.581	403	66.565	499	19.559	603	26
27	80.432	316	21.984	405	69.064	501	22.162	605	27
28	82.748	318	24.389	406	71.565	503	24.767	608	28
29	85.066	320	26.795	408	74.068	504	27.375	610	29
30	5087.386	2.320	5229.203	2.409	5376.572	2.506	5529.985	2.612	30
31	89.706	322	31.612	411	79.078	508	32.597	615	31
32	92.028	323	34.023	412	81.586	509	35.212	617	32
33	94.351	325	36.435	414	84.095	512	37.829	618	33
34	96.676	326	38.849	416	86.607	512	40.447	620	34
35	5099.002	328	41.265	417	89.119	515	43.067	621	35
36	5101.330	329	43.682	419	91.634	516	45.688	624	36
37	03.659	330	46.101	420	94.150	518	48.312	625	37
38	05.989	332	48.521	421	96.668	519	50.937	627	38
39	08.321	334	50.942	424	5399.187	522	53.564	628	39
40	5110.655	2.335	5253.366	2.425	5401.709	2.522	5556.192	2.630	40
41	12.990	336	55.791	426	04.231	525	58.822	632	41
42	15.326	338	58.217	428	06.756	526	61.454	634	42
43	17.664	339	60.645	429	09.282	528	64.088	635	43
44	20.003	341	63.074	431	11.810	530	66.723	637	44
45	22.344	342	65.506	433	14.340	531	69.360	640	45
46	24.686	343	67.938	435	16.871	533	72.000	641	46
47	27.029	345	70.373	436	19.404	535	74.641	643	47
48	29.374	347	72.809	437	21.939	537	77.284	645	48
49	31.721	348	75.246	440	24.476	538	79.929	647	49
50	5134.069	2.350	5277.686	2.440	5427.014	2.540	5582.576	2.649	50
51	36.419	351	80.126	442	29.554	542	85.225	650	51
52	38.770	352	82.568	444	32.096	544	87.875	653	52
53	41.122	354	85.012	445	34.640	545	90.528	654	53
54	43.476	355	87.457	448	37.185	547	93.182	657	54
55	45.831	357	89.905	449	39.732	549	95.839	658	55
56	48.188	358	92.354	449	42.281	551	5598.497	660	56
57	50.546	359	94.803	452	44.832	552	5601.157	662	57
58	52.905	361	97.255	454	47.384	554	03.819	664	58
59	55.266	2.363	5299.709	2.455	49.938	2.555	06.483	2.666	59
60	5157.629		5302.164		5452.493		5609.149		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	68° Meridional distance.	68° Difference.	69° Meridional distance.	69° Difference.	70° Meridional distance.	70° Difference.	71° Meridional distance.	71° Difference.	Minutes
	′	′	′	′	′	′	′	′	
0	5609.149	2.668	5772.739	2.789	5943.955	2.923	6123.602	3.071	0
1	11.817	670	75.528	791	46.878	925	26.673	073	1
2	14.487	672	78.319	793	49.803	927	29.746	076	2
3	17.159	673	81.112	795	52.730	929	32.822	078	3
4	19.832	676	83.907	798	55.659	932	35.900	081	4
5	22.508	678	86.705	800	58.591	935	38.981	084	5
6	25.186	679	89.505	801	61.526	937	42.065	086	6
7	27.865	682	92.306	804	64.463	939	45.151	089	7
8	30.547	683	95.110	807	67.402	941	48.240	092	8
9	33.230	685	5797.917	808	70.343	944	51.332	094	9
10	5635.915	2.687	5800.725	2.810	5973.287	2.947	6154.426	3.097	10
11	38.602	690	03.535	813	76.234	948	57.523	099	11
12	41.292	691	06.348	814	79.182	951	60.622	102	12
13	43.983	693	09.162	817	82.133	954	63.724	105	13
14	46.676	695	11.979	819	85.087	956	66.829	108	14
15	49.371	697	14.798	822	88.043	958	69.937	110	15
16	52.068	699	17.620	823	91.001	960	73.047	113	16
17	54.767	701	20.443	826	93.961	964	76.160	115	17
18	57.468	703	23.269	827	96.925	965	79.275	119	18
19	60.171	705	26.096	830	5999.890	968	82.394	120	19
20	5662.876	2.707	5828.926	2.832	6002.858	2.970	6185.514	3.124	20
21	65.583	709	31.758	835	05.828	973	88.638	126	21
22	68.292	711	34.593	836	08.801	975	91.764	129	22
23	71.003	713	37.429	838	11.776	977	94.893	132	23
24	73.716	715	40.267	841	14.753	980	6198.025	134	24
25	76.431	717	43.108	843	17.733	983	6201.159	137	25
26	79.148	719	45.951	846	20.716	985	04.296	140	26
27	81.867	721	48.797	847	23.701	987	07.436	143	27
28	84.588	723	51.644	850	26.688	990	10.579	145	28
29	87.311	725	54.494	852	29.678	992	13.724	148	29
30	5690.036	2.727	5857.346	2.854	6032.670	2.995	6216.872	3.151	30
31	92.763	729	60.200	857	35.665	997	20.023	153	31
32	95.492	731	63.057	858	38.662	2.999	23.176	156	32
33	5698.223	733	65.915	861	41.661	3.003	26.332	159	33
34	5700.956	735	68.776	863	44.664	004	29.491	162	34
35	03.691	738	71.639	866	47.668	007	32.653	165	35
36	06.429	739	74.595	867	50.675	010	35.818	167	36
37	09.168	741	77.372	870	53.685	012	38.985	170	37
38	11.909	743	80.242	872	56.697	015	42.155	173	38
39	14.652	746	83.114	875	59.712	017	45.328	175	39
40	5717.398	2.747	5885.989	2.876	6062.729	3.019	6248.503	3.179	40
41	20.145	749	88.865	879	65.748	022	51.682	181	41
42	22.894	752	91.744	881	68.770	024	54.863	184	42
43	25.646	753	94.625	883	71.794	027	58.047	187	43
44	28.399	756	5897.508	886	74.821	030	61.234	190	44
45	31.155	758	5900.394	888	77.851	032	64.424	192	45
46	33.913	759	03.282	890	80.883	035	67.616	195	46
47	36.672	762	06.172	893	83.918	037	70.811	199	47
48	39.434	764	09.065	895	86.955	040	74.010	201	48
49	42.198	766	11.960	897	89.995	043	77.211	203	49
50	5744.964	2.768	5914.857	2.899	6093.038	3.045	6280.414	3.207	50
51	47.732	770	17.756	902	96.083	047	83.621	210	51
52	50.502	772	20.658	904	6099.130	050	86.831	212	52
53	53.274	775	23.562	906	6102.180	052	90.043	215	53
54	56.049	776	26.468	909	05.232	055	93.258	218	54
55	58.825	779	29.377	911	08.287	058	96.470	221	55
56	61.604	780	32.288	913	11.345	061	6299.697	224	56
57	64.384	783	35.201	916	14.406	063	6302.921	227	57
58	67.167	785	38.117	918	17.469	065	06.148	230	58
59	69.952	2.787	41.035	2.920	20.534	3.068	09.378	3.232	59
60	5772.739		5943.955		6123.602		6312.610		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$]

Minutes.	72° Meridional distance.	72° Difference.	73° Meridional distance.	73° Difference.	74° Meridional distance.	74° Difference.	75° Meridional distance.	75° Difference.	Minutes.
	′	′	′	′	′	′	′	′	
0	6312.610	3.235	6512.071	3.420	6723.275	3.628	6947.761	3.864	0
1	15.845	238	15.491	423	26.903	631	51.625	868	1
2	19.083	242	18.914	426	30.534	635	55.493	872	2
3	22.325	244	22.340	430	34.169	639	59.365	877	3
4	25.569	247	25.770	433	37.808	643	63.242	881	4
5	28.816	250	29.203	437	41.451	646	67.123	885	5
6	32.066	253	32.640	439	45.097	650	71.008	890	6
7	35.319	256	36.079	443	48.747	654	74.898	894	7
8	38.575	259	39.522	446	52.401	658	78.792	898	8
9	41.834	262	42.968	450	56.059	662	82.690	902	9
10	6345.096	3.264	6546.418	3.453	6759.721	3.665	6986.592	3.906	10
11	48.360	267	49.871	456	63.386	669	90.498	911	11
12	51.627	271	53.327	459	67.055	673	94.409	915	12
13	54.898	273	56.786	463	70.728	676	6998.324	919	13
14	58.171	277	60.249	466	74.404	680	7002.243	924	14
15	61.448	279	63.715	470	78.084	684	06.167	928	15
16	64.727	283	67.185	473	81.768	688	10.095	933	16
17	68.010	286	70.658	476	85.456	692	14.028	937	17
18	71.296	288	74.134	480	89.148	696	17.965	941	18
19	74.584	292	77.614	483	92.844	699	21.906	946	19
20	6377.876	3.295	6581.097	3.486	6796.543	3.703	7025.852	3.949	20
21	81.171	297	84.583	490	6800.246	707	29.801	954	21
22	84.468	300	88.073	493	03.953	711	33.755	959	22
23	87.768	304	91.566	497	07.663	715	37.714	963	23
24	91.072	307	95.063	500	11.378	718	41.677	968	24
25	94.379	310	6598.563	504	15.096	722	45.645	972	25
26	6397.689	313	6602.067	507	18.818	727	49.617	977	26
27	6401.002	315	05.574	510	22.545	730	53.594	981	27
28	04.317	319	09.084	514	26.275	734	57.575	985	28
29	07.636	322	12.598	518	30.009	738	61.561	990	29
30	6410.958	3.325	6616.116	3.520	6833.747	3.742	7065.551	3.994	30
31	14.283	328	19.636	524	37.489	747	69.545	3.999	31
32	17.611	331	23.160	528	41.236	750	73.544	4.003	32
33	20.942	334	26.688	531	44.986	754	77.547	008	33
34	24.276	337	30.219	535	48.740	758	81.555	013	34
35	27.613	341	33.754	538	52.498	762	85.568	017	35
36	30.954	344	37.292	541	56.260	766	89.585	022	36
37	34.298	347	40.833	545	60.027	770	93.607	026	37
38	37.645	350	44.378	549	63.797	774	7097.633	031	38
39	40.995	353	47.927	552	67.571	778	7101.664	035	39
40	6444.348	3.356	6651.479	3.556	6871.349	3.782	7105.699	4.040	40
41	47.704	359	55.035	559	75.131	785	09.739	045	41
42	51.063	362	58.594	563	78.916	790	13.784	049	42
43	54.425	365	62.157	566	82.706	794	17.833	054	43
44	57.790	369	65.723	570	86.500	798	21.887	059	44
45	61.159	372	69.293	573	90.298	802	25.946	063	45
46	64.531	375	72.866	577	94.100	806	30.009	068	46
47	67.906	378	76.443	581	6897.906	810	34.077	072	47
48	71.284	381	80.024	585	6901.716	815	38.149	077	48
49	74.665	385	83.609	588	05.531	819	42.226	082	49
50	6478.050	3.387	6687.197	3.591	6909.350	3.822	7146.308	4.086	50
51	81.437	391	90.788	595	13.172	826	50.394	091	51
52	84.828	394	94.383	599	16.998	831	54.485	096	52
53	88.222	397	6697.982	602	20.829	835	58.581	101	53
54	91.619	401	6701.584	606	24.664	839	62.682	105	54
55	95.020	404	05.190	610	28.503	843	66.787	110	55
56	6498.424	407	08.800	613	32.346	847	70.897	115	56
57	6501.831	410	12.413	617	36.193	852	75.012	120	57
58	05.241	413	16.030	621	40.045	856	79.132	125	58
59	08.654	3.417	19.651	3.625	43.901	3.860	83.257	4.130	59
60	6512.071		6723.275		6947.761		7187.387		60

MERCATOR PROJECTION TABLE—Continued.

[Meridional distances for the spheroid. Compression $\frac{1}{294}$.]

Minutes.	76° Meridional distance.	76° Difference.	77° Meridional distance.	77° Difference.	78° Meridional distance.	78° Difference.	79° Meridional distance.	79° Difference.	Minutes.
0	7187. 387	4. 134	7444. 428	4. 447	7721. 700	4. 811	8022. 758	5. 243	0
1	91. 521	139	48. 875	452	26. 511	818	28. 001	251	1
2	95. 660	144	53. 327	458	31. 329	825	33. 252	259	2
3	7199. 804	149	57. 785	463	36. 154	831	38. 511	267	3
4	7203. 953	154	62. 248	469	40. 985	838	43. 778	275	4
5	08. 107	159	66. 717	475	45. 823	845	49. 053	283	5
6	12. 266	163	71. 192	481	50. 668	852	54. 336	292	6
7	16. 429	169	75. 673	487	55. 520	858	59. 628	299	7
8	20. 598	174	80. 160	492	60. 378	865	64. 927	307	8
9	24. 772	178	84. 652	498	65. 243	872	70. 234	316	9
10	7228. 950	4. 183	7489. 150	4. 504	7770. 115	4. 878	8075. 550	5. 323	10
11	33. 133	188	93. 654	509	74. 993	885	80. 873	330	11
12	37. 321	193	7498. 163	515	79. 878	892	86. 203	339	12
13	41. 514	198	7502. 678	521	84. 770	899	91. 542	348	13
14	45. 712	203	07. 199	527	89. 669	906	8096. 890	356	14
15	49. 915	208	11. 726	532	94. 575	912	8102. 246	364	15
16	54. 123	213	16. 258	539	7799. 487	920	07. 610	373	16
17	58. 336	219	20. 797	544	7804. 407	927	12. 983	381	17
18	62. 555	223	25. 341	550	09. 334	933	18. 364	389	18
19	66. 778	229	29. 891	556	14. 267	941	23. 753	397	19
20	7271. 007	4. 233	7534. 447	4. 561	7819. 208	4. 947	8129. 150	5. 405	20
21	75. 240	238	39. 008	567	24. 155	954	34. 555	414	21
22	79. 478	243	43. 575	574	29. 109	961	39. 969	422	22
23	83. 721	249	48. 149	579	34. 070	968	45. 391	430	23
24	87. 970	254	52. 728	585	39. 038	975	50. 821	439	24
25	92. 224	258	57. 313	592	44. 013	983	56. 260	448	25
26	7296. 482	265	61. 905	597	48. 996	990	61. 708	457	26
27	7300. 747	269	66. 502	604	53. 986	4. 997	67. 165	465	27
28	05. 016	274	71. 106	610	58. 983	5. 004	72. 630	474	28
29	09. 290	280	75. 716	616	63. 987	011	78. 104	482	29
30	7313. 570	4. 284	7580. 332	4. 621	7868. 998	5. 018	8183. 586	5. 490	30
31	17. 854	290	84. 953	628	74. 016	025	89. 076	499	31
32	22. 144	295	89. 581	634	79. 041	032	8194. 575	507	32
33	26. 439	300	94. 215	640	84. 073	040	8200. 082	516	33
34	30. 739	306	7598. 855	647	89. 113	047	05. 598	525	34
35	35. 045	311	7603. 502	652	94. 160	054	11. 123	534	35
36	39. 356	316	08. 154	659	7899. 214	062	16. 657	543	36
37	43. 672	322	12. 813	665	7904. 276	069	22. 200	552	37
38	47. 994	327	17. 478	671	09. 345	076	27. 752	561	38
39	52. 321	332	22. 149	678	14. 421	084	33. 313	570	39
40	7356. 653	4. 337	7626. 827	4. 683	7919. 505	5. 091	8238. 883	5. 578	40
41	60. 990	342	31. 510	689	24. 596	098	44. 461	586	41
42	65. 332	348	36. 199	696	29. 694	105	50. 047	595	42
43	69. 680	353	40. 895	702	34. 799	113	55. 642	605	43
44	74. 033	359	45. 597	708	39. 912	121	61. 247	614	44
45	78. 392	364	50. 305	715	45. 033	128	66. 851	623	45
46	82. 756	370	55. 020	721	50. 161	136	72. 484	633	46
47	87. 126	375	59. 741	728	55. 297	144	78. 117	642	47
48	91. 501	381	64. 469	734	60. 441	151	83. 759	650	48
49	7395. 882	386	69. 203	740	65. 592	159	89. 409	660	49
50	7400. 268	4. 391	7673. 943	4. 746	7970. 751	5. 166	8295. 069	5. 668	50
51	04. 659	396	78. 689	753	75. 917	173	8300. 737	677	51
52	09. 055	402	83. 442	759	81. 090	181	06. 414	687	52
53	13. 457	408	88. 201	766	86. 271	189	12. 101	697	53
54	17. 865	413	92. 967	773	91. 460	196	17. 798	706	54
55	22. 278	419	7697. 740	779	7996. 656	205	23. 504	715	55
56	26. 697	424	7702. 519	785	8001. 861	213	29. 219	725	56
57	31. 121	430	07. 304	792	07. 074	220	34. 944	734	57
58	35. 551	436	12. 096	799	12. 294	228	40. 678	744	58
59	39. 987	4. 441	16. 895	4. 805	17. 522	5. 236	46. 422	5. 754	59
60	7444. 428		7721. 700		8022. 758		8352. 176		60

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